Brick Drying

Arthur Edward Brown

BRICK DRYING.

A Practical Treatise on the Drying of Bricks and similar Clay Products.

BY

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With 125 illustrations and 11 tables.

London:
"THE CLAYWORKER PRESS,"
43, Essex Street, Strand, W.C.

1902.

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BRICK-DRYING.

CHAPTER I.

Scope of Treatise.

It is proposed in a short treatise to look somewhat closely into the science and practice of brick drying. In confining the papers to brick drying especially, it does not follow that much which is stated does not apply to the drying of the more high class and artistic of the wares known in the ceramic industry, and some mention will be found of the treatment of such other wares in dealing with the general sub-division of the subject.

Natural and Artificial Drying.

To the brickmaker, the practice of drying bricks seems to divide itself obviously into two sections; drying without heat or natural drying, and drying with heat or artificial drying. When examined scientifically, it is at once seen that this mode of expression is inaccurate, and that the correct way to describe the two methods of proceeding is:—Drying by large volume of air at ordinary temperature, and drying by small volume of air at artificially increased temperature.

No drying, *i.e.*, evaporation of water or moisture, can take place without absorption of heat. This fundamental fact is often lost sight of by the practical man, because a large volume of air will yield the requisite heat for the evaporation, without appreciable reduction of temperature

FUNDAMENTAL SCIENTIFIC FACTS.

In order to put the scientific facts with regard to evaporation of water in a manner easily appreciated by the unscientific, it may be stated that one pound of water at 62° F. requires the same amount of heat to evaporate it as would cause 7½ pounds of water at 62° to boil.

Yet the one pound of water may be evaporated out of a brick, without the brick or the water being heated above 62°. But to perform this operation a certain volume of air must be provided at a rather higher temperature than 62° to yield the requisite heat and to carry off the vapour of water.

ABSORPTIVE POWER OF AIR.

The second scientific feature of the phenomenon of evaporation of water is the capacity of air at all temperatures for carrying or containing moisture. This property of air is of the most vital importance in all questions of drying, because on it depends the success of all special methods of obtaining the desired end.

The amount of moisture or vapour of water which air can carry, varies with the temperature. At every temperature below boiling point of water or 212° F. it will carry a certain definite maximum amount. When this amount is reached, the air at that particular temperature is saturated. If now the temperature of the air is lowered by giving up some of its heat to a colder body, some of the vapour immediately becomes condensed, forming dew. The temperature of saturation is also called the dew point, because of this phenomenon. Ultimately the colder body, the dew, the air, and the moisture in the air will, if undisturbed, all attain one common temperature, and the air will still be saturated with the maximum amount of vapour, which it can carry at the lower temperature.

Suppose now that the air, instead of being cooled, is warmed to a higher temperature, it will then no longer be saturated with moisture, but will be capable of taking up an additional quantity. If then a moist body be introduced into the warmed air, some of the moisture will be evaporated or dried out of it. This will continue until a new condition of equilibrium is

obtained. Either the body will be completely dried; or the body, the moisture in the body, the air and the vapour in the air will all attain one uniform temperature. In the latter case the air will be completely saturated with vapour, and incapable of taking up more.

Subjoined is a table giving the weights and volumes of air under mean pressure at a few different temperatures, which will contain, when saturated, 1 lb. of water in the form of vapour.

TABLE I.

Temperature.	Weight of Air.	Volume of Mixture.
42	178·18 lbs.	2272 cubic feet.
52	122·17 ,,	1595 ,,
62	84·79 ,,	1135 ,,
72	59·54 ,,	819 ,,
82	42·35 ,,	600 ,,
102	21·98 ,,	333 ,,
132	8·49 ,,	151 ,,
182	1·402 ,,	48·7 ,,

The striking feature of the table is the rapid decrease in the quantity of air necessary as the temperature of it increases. It also shows that in the example quoted above, it is only necessary to raise again the temperature of the air to enable it to take up a further portion of water from the moist body.

A curious feature in the behaviour of vapour and air is the fact that the addition of the one to the other causes but very slight alteration in volume. The air contained in a saturated mixture at mean temperature and pressure would, if dry, occupy 98½ per cent. of the space occupied by the mixture.

Saturated air is rather less in weight than the same volume of dry air. The actual weights of a cubic foot of dry and saturated air at 60° F. under a pressure of 30 inches of the barometer being 536·3 grains and 532·7 grains respectively.

In dealing with air as we find it in this country's climate, we have to take account of the amount of moisture already contained in it at ordinary temperatures. It is usually large; on an average 66 per cent. of the amount at saturation. In damp weather it usually exceeds this proportion, frequently attaining saturation, and in the driest weather it seldom falls below 40 per cent.

HYGROSCOPES.

Several forms of instrument are used for indicating the amount of moisture in the air, or for testing its drying capability. The wet and dry bulb thermometer here illustrated, Fig. 1, is perhaps the most reliable, though, except in skilled hands, most of them can only be taken as indicators rather than measurers, as they are dependent on their position, on the air currents, wind and radiation, for their accuracy of registration.

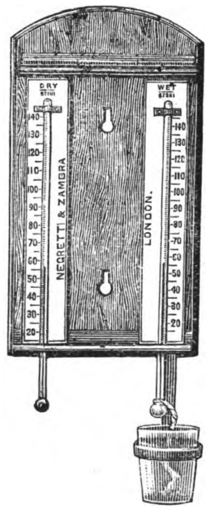


FIG. 1.

As will be seen from the illustration, one thermometer indicates the temperature of the air. The bulb of the second is kept continually moistened with water by means of a reservoir, wick, and muslin covering to the bulb. The evaporation of water from the covering absorbs heat from the mercury in the thermometer bulb, and causes it to register a lower temperature than the uncovered thermometer.

The difference of temperature shown on the two thermometers is an indication of the rate at which the air is drying water from the cotton covering.

This instrument at the same time illustrates the fact that heat is absorbed in the process of evaporation.

In this country the average difference shown on the thermometers is 5° in summer and 1° in winter. In tropical dry climates it attains as much as 12°.

Messrs. Negretti & Zambra issue with their instruments a pamphlet by Mr. James Glaisher, F.R.S., containing tables for use with the wet and dry bulb thermometer. With their aid the humidity of the atmosphere can at any time be estimated.

Such then, are the fundamental and important facts in connection with evaporation of water, and it will be seen later the bearing they have on the various processes in use for drying bricks.

NATURAL DRYING EXPLAINED.

It will be instructive now to examine the conditions which obtain in the old and still much used method of open-air drying of bricks on the ground or in hacks. A description of the methods will be given later, but it is proposed here to demonstrate the science of the process.

A stock brick as produced in Kent and Essex, will contain, when made, about 2 lbs. of water, and when dry, ½ lb., showing that water of manufacture to the amount of about 1½ lbs. is dried out of it.

Now at 62° F. this requires 1,606 English units of heat for its evaporation. A unit of heat is the amount required to heat 1 lb. of water 1° F., and the above quantity is yielded by the burning of about 2¼ oz. of ordinary coal.

In outdoor drying the source of heat is the sun, which warms the air. The air in its turn gives up heat in evaporating the water.

Now presuming that the stock brick takes a fortnight to dry and loses its moisture at a uniform rate throughout that time, it will be seen that it requires 4¾ units of heat per hour to perform the drying. Presuming that the air passing over the bricks loses 1° only in giving up heat to the brick, it will require

$\frac{4.75}{1 \times .237} = 20$ lbs. of air to supply the requisite heat per hour.

In this calculation .237 is the Specific Heat of air, that of water

being 1. This weight of air corresponds to 265 cubic feet at 63°. Thus if the brick is subjected to a current of air of ¼ of a square foot in section (36 square inches), the speed of the current necessary would be 1060 feet per hour, or one-fifth of a mile only. Such a speed of air movement is practically too slight to be felt. It can be seen further that if this current of air contained 63% of moisture, it would contain 67% after passing over the brick and being reduced 1° in tempetature.

It is evident, therefore, that in outdoor drying in summer the changes in temperature and humidity of air, when there is a moderate wind, are so small as to be inappreciable. Nevertheless, the actual conditions are of such importance that at average temperatures and humidity of air, drying is not possible outdoors in this country in winter, even apart from the consideration of danger of freezing.

The Drying of a Brick.

It is of importance now to consider the process of drying within the brick itself and to see how it is affected by different influences of material and method and speed of drying.

Material.

When a brick is made by plastic process the clay has added to it "water of manufacture" in various proportion, according to the nature of the clay and the method of manufacture adopted. In a brick, in a truly plastic condition, this water fills all the interstices in the clay so that no air is enclosed in it except accidentally.

At a certain consistency, such as it has when fit for being formed into a brick, clay is in a pasty condition due to the particles being more or less close together, and it may be described as being traversed throughout by minute pores filled with water. The finer the clay particles, the smaller and the more numerous the pores. Thus, the purer a clay and the finer its particles, the more porous it is.

Porosity and Permeability.

At first sight this seems contrary to experience, but it is necessary further to explain that porosity must be distinguished

from permeability. The finer the pores in clay, the more difficult it is for water to pass through them, because of the great resistance which the surface tension of water exerts at the ends of fine tubes. One can test this in a simple manner with fine glass tubes. Take a tube with a bore, say, of one-eighth of an inch, and see with what ease one can suck up water into it, and expel it again. Now try the same with a broken thermometer tube and the difficulty or impossibility of doing it will be at once apparent. A proof that strong clays are actually more porous than sandy ones, is found in the fact that they take a larger percentage of water of manufacture to make them sufficiently plastic for moulding.

In spite of the smallness of the pores, heat is able to act on the surfaces of the water in the tubes, causing evaporation. Capillary action then commences, and the internal water moves through the pores towards the surface.

The properties, then, of a pure clay, are porosity and impermeability. Now, as sand or other particles are mixed with clay, so the porosity decreases, and the permeability increases, the relative difference depending on the proportion, shape, and size of the particles. The greatest permeability and least porosity are found in clay containing large particles of irregular shape. The projections on the particles catch against one another, preventing contraction of the mass of the earth. The pure clay is not sufficient in quantity to fill completely the spaces between the particles, thus leaving comparatively large channels through which water can pass. The channels are, nevertheless, much fewer in number and less in total volume than the pores in a strong clay.

PHYSICAL PHENOMENA IN THE DRYING PROCESS.

The process of drying clays when made into bricks, varies with these qualities of porosity and permeability. When drying a porous strong clay, the water at first evaporates from the surface and is replaced by capillary action from the interior, the brick contracting by the same amount as the water diminishes. The pores remain all filled with water until the rate of evaporation exceeds the rate at which the pores transmit the water.

This point occurs when the clay particles move so much less freely on each other, that the rate of evaporation exceeds in volume the rate of contraction. After the first stage of surface-drying, the exterior of the brick loses water more rapidly than the interior. In the second stage now reached, the pores are no longer filled with water at their outer ends, and begin to form spaces in the brick, filled with air and vapour. Contraction still occurs throughout this second stage until the substance of the clay is so far solidified that the individual particles can no longer slip on each other at all. The third stage is then reached, in which capillary action and shrinkage cease entirely. Evaporation now takes place entirely inside the brick, and spaces are formed exactly corresponding with the volume of water lost.

Scumming in Drying.

In a strong clay, the long duration of the first stage and its accompanying capillary action is the cause of the scumming which occurs in drying. The soluble salts in the clay are held in solution by the water, and are deposited on the surface by it as it evaporates. If the surface-drying is of short duration, the salt deposited is almost inappreciable, but the longer the duration the more the deposit. Excess of water on the surface of the brick caused by the lubrication of a machine die or a coating of oil, will increase the duration of surface-drying. The effect is frequently illustrated by the marks seen on strong clay bricks after burning, where workmen's oily fingers have touched the faces. The coating of oil has lengthened the duration of surface-drying where the fingers have touched the brick. In firing in the kiln, the soluble salts are largely converted into insoluble ones by combination with the silica of the clay, or by combination with the sulphur in the coal and the alumina of the clay.

Means of Diminishing Scumming.

This form of scumming can be diminished, if not altogether prevented, in several ways, and it would perhaps be of value to mention them at this point.

By sanding the surface of the brick a greatly increased evaporation can be obtained in the first stage from the actual

surface itself. The effect of this is to form a very thin skin of drier clay through the many interstices of which the evaporation of the first stage is completed. The salts, instead of being deposited outside on the face, are left for the greater part just below this skin, and are not seen.

By a rapid evaporation in the earlier part of the first stage of drying a similar effect may be produced.

By applying a thin coating of flour paste, which is very porous, the deposit of salts in drying is formed on the surface of the paste instead of on the clay. When fired, the salts are not in sufficiently close contact with the clay to enter into combination with it, and can be brushed or washed off. The flour, of course, is burned away in the kiln.

By washing or painting the faces with a slip of the same clay, when the brick is dry or half dry, an effect is produced which needs no explanation. It is a process largely in use in the manufacture of architectural terra-cotta.

By the admixture of a certain proportion of carbonate of baryta with the clay when pugging, an insoluble compound is formed with such soluble sulphates as are present, and this consequently remains in the body of the brick. This process has no effect on soluble nitrates and chlorides, which may be present in the clay, and is, therefore, only a partial remedy depending on the salts present. It is well to have an analysis of the clay before trying this remedy.

Returning now to the consideration of the physical phenomena of drying, it is evident that the same three stages are operative in the case of a brick made of permeable, sandy clay. The first stage is, however, much shorter in proportion, for three reasons:—A smaller proportion of water of manufacture is added to the clay, capillary action is less operative in the larger spaces between the particles, and the evaporation is more rapid in proportion to the shrinkage. The danger of scumming is consequently much reduced, but even with these clays it occurs frequently in the damp, cold weather of late autumn, in out-door drying.

Diagrams of Brick Drying.

Experiments on many samples of clays give figures bearing out the preceding statements, and graphic representations of the results as shown in the diagrams, Figs. 2, 3, 4 and 5, are obtained.

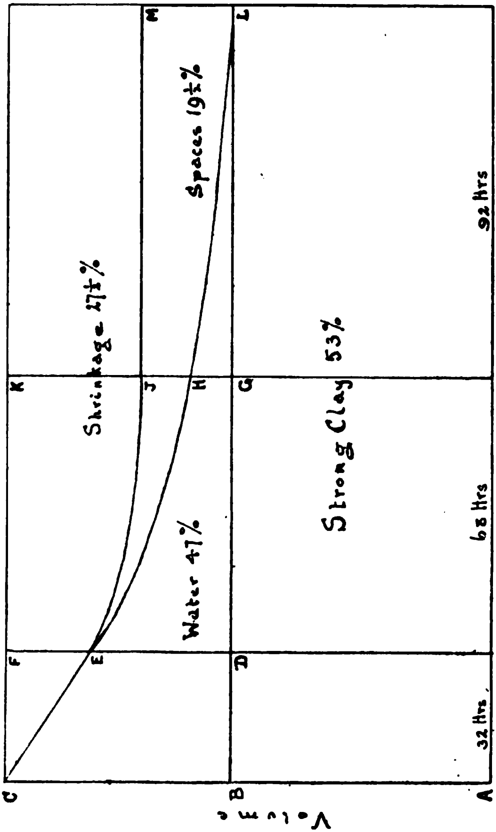


FIG. 2.

In these figures the vertical lines represent volumes and indicate volume of clay, water, spaces and shrinkage of a brick at different stages. Each figure is divided by its vertical lines

into the three stages of drying before described. The extent of the horizontal line represents time in drying. In each figure A B is the volume of clay, and B C the water at the commencement. At the end of the first stage, taking B D hours, the volume of water remaining in the brick is D E, and the shrinkage in volume is E F.

At the end of the second stage, taking D G hours, the volume of water is reduced to G H, and the shrinkage (now complete) is

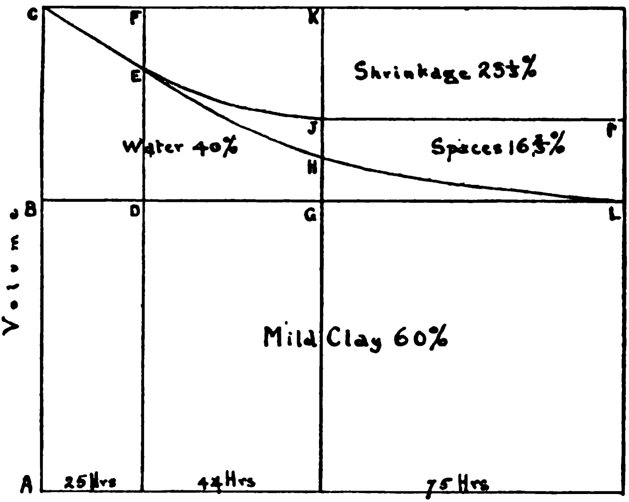


FIG. 3.

J K. It is consequently evident that there is a volume H J of spaces in the brick. At the end of the third stage, which is reached in G L hours, the water is gone, and as the brick has not shrunk further, the volume of spaces in the brick must be L M. These diagrams (Figs. 2, 3, and 4,) bring into prominence the variations obtaining as the clay is more and more sandy, showing the decrease, (1) in the time of drying, especially in the first two stages; (2) in the water necessary for manufacture; (3) in the shrinkage; and (4) in the spaces in the dry brick.

Fig. 5, which represents the results obtained with china clay dried under the same conditions, is interesting, as it shows the difference in character between plastic earths and kaolins. Here the first stage is very short, the water of manufacture is large, the drying is quick, the shrinkage is small, and the spaces considerable in volume in the dry clay.

It must be stated that these diagrams are *typical* only of the various qualities of plastic clay and not absolute or invariable.

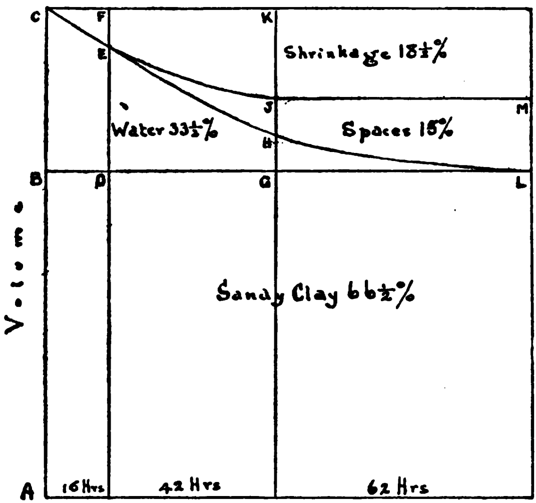


FIG. 4.

The method of obtaining them is as follows:—

Bricks are made of one standard size from various qualities of clay, half-a-dozen or so being made of each kind selected. They are all weighed and measured carefully, and all are placed at the same time in a chamber warmed and ventilated in a uniform manner.

The bricks are maintained in this uniformly-drying atmosphere till they are dry and are weighed and measured at regular intervals. During the first stage they must be very frequently

measured, during the second less frequently, and during the third at still longer intervals.

The loss in weight at each measurement gives the loss of water by evaporation, whereas the change in dimensions gives the loss in volume of the brick. The *volume* of water lost by evaporation is easily calculated from the weight by the known relation that one cubic inch of water weighs 0·578 oz.

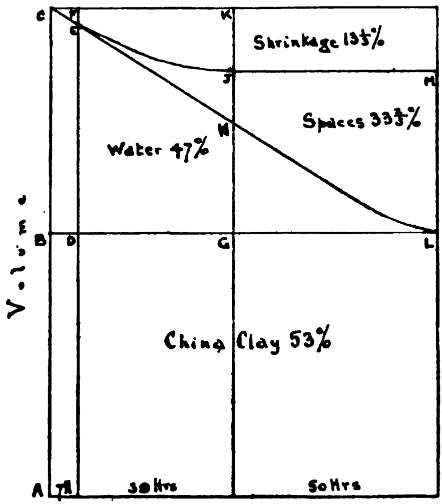


FIG. 5.

Now as soon as the loss in weight commences to be greater (in its equivalent volume) than the loss of volume of the brick by shrinkage, the first stage of drying is completed and the point E determined.

The end of the second stage is determined simply by the cessation of change in the dimensions of the brick.

The actual volume of clay in a brick is calculated by deducting the volume of water lost in drying, from the original volume of the wet brick.

The percentages given are percentages of the total original volume of the wet brick, which is taken of course as 100,

The numerical statement of the results of the experiments on, for instance, the clay used for Fig. 3, is as follows:—

TABLE II.

Time Drying. Hours.		Volume of brick. Per cent.	Volume of water lost. Per cent.	Consequent volume of spaces in brick. Per cent.
1st Stage	0	100·0	0·0	0
	12	94·0	6·0	0
	25	87·5	12·5	0
2nd Stage	36	83·0	18·5	1·5
	48	80·0	24·5	4·5
	60	78·0	29·0	7·0
	69	76·6	31·0	8·0
3rd Stage	72	76·6	32·0	9·0
	84	76·6	34·0	11·0
	108	76·6	37·5	14·5
	144	76·6	40·0	16·6

The figures are here stated for approximately every twelve hours, to save space and unnecessary detail, but the actual measurements are of course taken much more frequently. The results tabulated are the means of several sets of measurements on each kind of clay.

EFFECT OF CONSISTENCY.

If a clay is made by hand, it must be prepared in a sufficiently soft condition to fill the moulds completely, and, therefore, requires the addition of more water of manufacture than if made by machine. It is of interest, therefore, to point out the effect on the shrinkage and the volume of spaces when dry, of the addition of different quantities of water to the same clay. Taking 100 parts by volume of an average mild clay such as that illustrated in Fig. 3 experiment shews that:—

TABLE III.

With the addition to the dry clay of:—	A shrinkage in volume when dried will occur of:—	And the spaces will be of the total volume of the dry brick:—
* 10 per cent. water.	4 per cent.	21 per cent.
15 ,, ,,	11 ,, diff. 7	22½ ,, diff. 1½
20 ,, ,,	20 ,, ,, 9	24½ ,, ,, 2
25 ,, ,,	30 ,, ,, 10	27 ,, ,, 2½

* Of these quantities 5 per cent. is in each case hygroscopic water, which is not dried out till steamed in the kiln.

This table shews that the less the water used in manufacture the more solid is the resulting brick.

If, now, the bricks made with varying amounts of water of manufacture are subjected to exactly the same conditions of drying, the rate is not proportional to the amount of water added, but takes longer in proportion for those with less water. It takes approximately proportional time in the first two stages of drying, but the more solid the brick, the longer it takes to eliminate the water in the last stage. It follows also from this, that want of uniformity in the substance of a brick, such as must exist in bricks made by hand, and in a less degree in those made through a die or in a press, causes a corresponding want of uniformity in the shrinkage and rate of drying in different parts of it. This is one cause of the warping or twisting of bricks in drying.

Effect of Rapidity in Drying.

The shrinkage of a brick is also affected by the rapidity with which it is dried, a point which is noteworthy, because of the increasing use of rapid-drying systems at the present time. The shrinkage is less with rapid drying, probably because the clay particles do not have time to accommodate themselves so perfectly to new positions in the course of the process.

Experiment has shewn that on bricks made with a given sample of clay, the shrinkage of one dried in 48 hours was 7¾ per cent. lineal, and of one dried in 15 days was 8½ per cent.

Effect of Size and Shape.

In all classes of clay, the brick in the second stage of drying loses water more rapidly on the outside than in the inside, the angles and arrises in their turn drying more rapidly than the faces. The consequent shrinkage of the outer layer is the frequent cause of cracking, and it is therefore necessary to pursue this stage with great caution, and to effect the drying with air already heavily charged with moisture. It is also for this reason essential to avoid excessive prominence of any part of a shaped brick, and it is advisable to follow the shaping with hollows so as to maintain an approximately regular thickness of material throughout. The frogs or indents on both

sides of a common brick are serviceable in drying for the same reason. In a re-pressed brick they serve also the additional purpose of rendering the consistency more even throughout.

For objects of reasonable size the rate of drying is approximately proportional to the ratio of surface to volume. Objects of large size, however, take much longer to dry, and require the application of considerable heat to complete the removal of all the water of manufacture from the interior. Many large goods made of fire-clay and stoneware clay require extremely careful treatment, and have to be kept in a heated atmosphere for several days after the moisture has apparently all been removed. Disastrous results are frequently known to occur in the steaming operations in the kiln for want of sufficient care in this particular. Manufacturers frequently adopt a wise precaution in having such goods stamped with the date of making, and in holding their workmen responsible if they are rendered unsound by being burnt before the lapse of a stated period of drying.

CHAPTER II.

Sub-Divisions of Practice of Drying.

The practice of drying as before stated divides itself naturally into two sections :—(1) Drying by a large volume of air at ordinary temperature, and (2) drying by a less volume of air at artificially increased temperature. To this may be added a third method in use in the potteries, but not used in brick manufacture ; that of drying by absorption.

Drying by Absorption.

To notice it in passing, it should be stated that it is a method in which moulds are used, made of plaster of Paris. This material, when dry, absorbs moisture rapidly from clay in contact with it. There are several important precautions to be observed in the manufacture of the moulds, and they must be

dried after use to fit them for the same function on the next occasion. The method serves to stiffen moulded pottery, such as lavatory basins, closets, and other large ware, so that when removed from the moulds it may be handled without deformation.

As this process is not used in brickmaking, it is not necessary to go into its details in this treatise.

Open-Air Drying.

The oldest and most used method of drying bricks is by large volume of air at ordinary temperature. This is practised in a variety of ways, simplest of all of which is, open-air drying without protection of any kind. Even at the present day this method is in use on the Continent. A level piece of ground is evenly spread over with sand upon which newly made bricks are placed in rows on their edges. This method is to be seen in practice near Buda-Pesth, in Hungary, without provision being made for protection at any time. In some places the bricks are only left so exposed until sufficiently stiffened to be picked up and stacked in hacks or blocks. When so stacked they are skintled in a manner to be presently described, and they are protected by a covering of straw till ready for burning. An improvement on this primitive method is known as drying on hacks.

The Hack Ground.

An even surface of ground of suitable extent is selected and a series of straight hacks constructed on which to place the bricks. Due care and forethought are necessary in deciding the direction of the hacks. The most important consideration in determining this, is provision for cheap and efficient drainage, as it is essential above all things that the ground should not be liable to become flooded by storms, or to retain water and remain damp long after rain.

The most suitable direction, if possible, is due north and south, so that both sides of a hack may receive an equal amount of sunshine, and so that neither side may be subject to the direct rays of the midday sun. Some authorities are of opinion that the hacks should be constructed broadside to the most

prevalent winds, but it is manifestly preferable to make them end on to the direction of storms, so that neither side is directly exposed to their effects. It is also preferable to give the strong wind play directly through the pathways between the hacks, so that moisture is carried away equally throughout.

If possible, therefore, in this country the hacks should extend either north to south, or north-east to south-west.

The ground being selected, and the direction of the hacks determined, it is necessary to insert next, just below the general level of the ground, such conduits as may be necessary to carry off rain rapidly and completely. Agricultural land-drain-pipes in 12-in. unsocketted lengths, and 3-in. internal diameter, are efficient for drainage when the pathways of the hacks do not slope suitably to carry off water without such aid. These should be placed under the hacks and under the pathways in the requisite direction, and at intervals of 10 or 15 yards apart.

The centres of the hacks should be spaced from 10 to 12 feet apart, and the hacks themselves formed 2ft. 6in. wide. They should be made about 4in. high above ground level, by banking up a layer of earth which may be afterwards topped with clean sand, evenly spread. It is a very good practice, serving at the same time to provide drainage and form the raised hacks, to turn up the soil from small trenches along the sides of each hack, and down the middle of each pathway, as indicated in cross section by the diagram (Fig. 6).

This diagram, at the same time, shows the land drain pipes before mentioned as a provision for carrying off water transversely when required. Hacks are usually constructed of considerable length, 80 yards being perhaps an average. A ground to carry a million during our summer season would require 16 to 18 hacks of this length. The whole ground therefore for this output will occupy a space 80 yards long and 64 yards broad, or exactly one acre. It is practically not possible with most clays to fill and dry each hack more than four times in our summer season

Hack Setting.

Each hack is constructed to carry two *blades* or rows of bricks set on edge, there being a space of about 8ins. between the

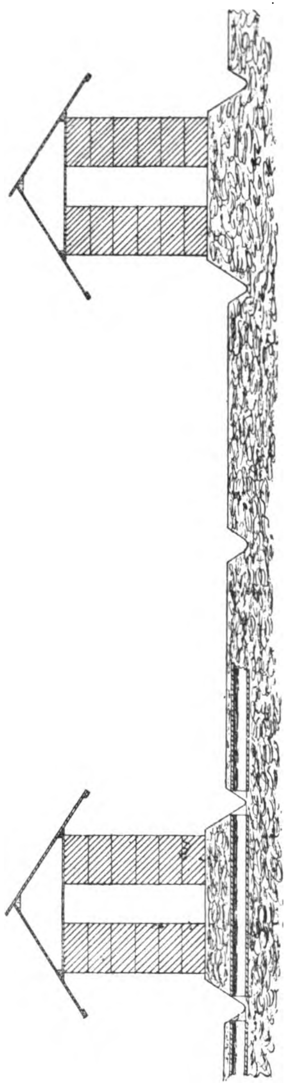


FIG. 6.

blades. The bricks themselves are separated from one another in hacking, by means of the *setting board*, by a space of three-eighths to five-eighths of an inch, the bricks in the second row covering the spaces between those in the first row on which they are set (Fig. 7). The bricks may be set as much as 8 or 9 high,

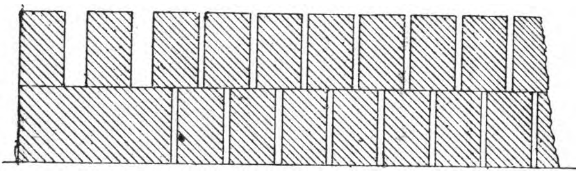


FIG. 7.

but this must be done gradually, the whole ground row being set first, then the whole second row and so on. This is necessary in order that the bricks below may get sufficiently stiffened to bear the weight of those above them. The setting board which is used to space the bricks is of the same dimensions as the pallet board, but of the special thickness decided on in each particular brickyard. It is retained in the hand of the hack-setter after setting each brick, the pallet boards being replaced on the off-bearing barrow.

When wire-cut bricks are set on hacks the bricks are taken from the boards one or two at a time by means of two small pallets, one in each hand of the setter, which are placed on the ends of the bricks to hold them when lifted. Manufacturers should never allow the workmen to do this with their bare hands.

HACK COVERS.

Three methods are in use for covering open hacks apart from protection of the sides. The first and most primitive is by means of loose straw. For this purpose hard and long wheat straw is necessary. A wisp is laid longitudinally on the bricks, and on that a thick layer transversely, extending well over both sides. This method is expensive and wasteful, and is superseded in these days by the use of (2) portable hack covers, either of straw or wood, or (3) erected hack roofing. Wood

is preferable for hack covers, in the majority of cases, but straw is essential with clays liable to crack and warp in the earlier stages of drying. The wood cover transmits a good deal

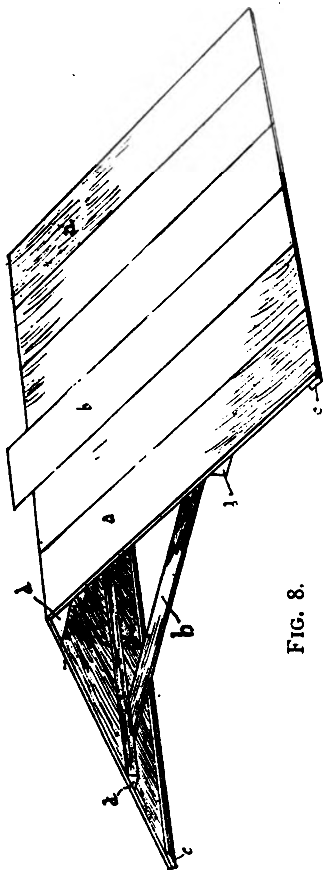


FIG. 8.

of heat on sunny days, and also allows more circulation of air along the top row of bricks than is admissible in such cases. Either wood or straw covers are conveniently made 1 yard in

length and 3½ to 4 feet wide. This size is portable and easily handled without damage. The wood hack cover here illustrated (Fig. 8), is constructed of :—

11 boards 2ft. 3in. by 6in. by ⅜in. (*a*)
3 „ 2ft. 6in. by 6in. by ⅜in. (*b*)
2 fillets 3ft. by 1½in. by ⅝in. (*c*)

1 ridge and 2 purlins (*d*) cut out of a batten 3ft. by 4in. by 1¼in., in the way illustrated by Fig. 9. Two of the boards,

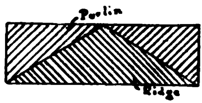


FIG. 9.

2ft. 6in. by 6in., are nailed across from purlin to purlin as "collars" serving to hold the cover to shape and at the same time to support it on the hack of bricks. The third board, 2ft. 6in. long, projects at the ridge, forming a convenient means of handling.

The wood for these hack covers, ready sawn and bundled, may be bought sometimes from firewood-timber merchants as cheaply as 10d. per set, but usually it costs 1/1 or 1/2 per set. The making up is worth from 2d. to 3d. each.

The hacks of bricks are also protected at one or both sides by sacks, mats or boards. The Petersburgh imported bast mats, 6ft. by 3ft., costing about 6d. each, are used largely for the purpose, keeping off sun and wind, but allowing the passage of a moderate quantity of air.

LOO-BOARDS.

Boards for side protection of the bricks, called variously *Loo*, *lew* or *lewin*-boards are conveniently made in 6ft. lengths, 2ft. 6in. wide. Corresponding with the use of straw or wood covers, these may be made of straw or wood. For those made of wood, the top boards should be three-quarters of an inch thick, and the others half an inch. Two of the bracing ledges may be extended to a length of 3ft. 6in. to

form legs as shewn in Fig. 10. They should be 3in. by 1½in., and the middle one 2in. by 1½in.

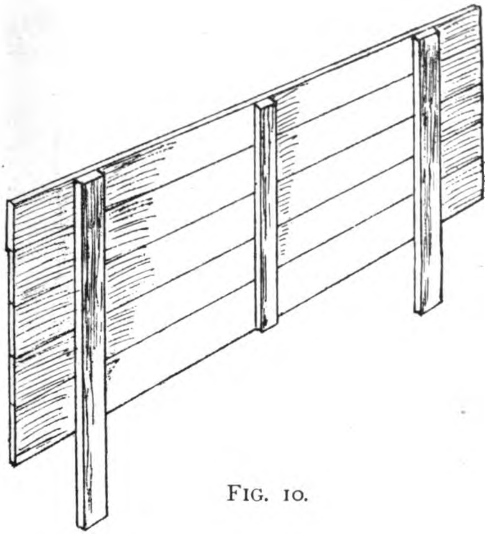


FIG. 10.

Such are the usual provisions for protection of bricks against weather on an open hack ground. For a common brick they have the merit of cheapness and portability, and in winter they can be packed away under cover. The yearly repair bill is however a considerable item.

SKINTLING.

After a hack is filled 8 or 9 high, the bricks are allowed sufficient time to become stiff enough to handle with one hand, a condition attained by hand-moulded bricks in one-third to one-half of the time required for complete drying. On reference to the diagrams (Figs. 2, 3 and 4, pp. 10, 11 and 12), it will be seen that shrinkage is nearly complete by this time and danger of cracking is practically passed. The bricks are then *skintled*, with the exception of the two or three bottom rows which are considerably drier than the upper ones. A short portion of the hack being cleared at one end, the bricks

are picked up, one in each hand at a time, and set on the cleared space diagonally on the blade, and one inch apart. The bricks in one row are crossed now at right angles by those in the next, and the hack is set one brick higher to allow for the additional space taken up. Fig. 11 illustrates this practice in plan.

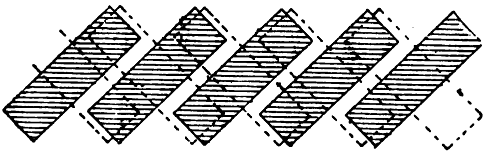


FIG. 11.

The hack does not after skintling require so much protection against wind and sun, and both covers and loo-boards may be removed during the daytime on fine days.

SKINTLING FOR PRESSING.

When hack-dried bricks are to be pressed, the skintling must be done at an earlier stage. The bricks must be handled one at a time with both hands, and the end originally next the pathway turned inwards for the double purpose of preventing that end from much further stiffening, and of obtaining an increased stiffening of the end previously turned inwards. A day or two later the bricks will attain a fairly uniform consistency suitable for the pressing operation, after which they are again set in skintle for final drying. When hacking bricks intended to be pressed, it is advisable to stack them only six high, and to set the two bottom rows with common bricks which will not be pressed. Mats or sacks are also frequently used for protecting the outer ends of the bricks against excessive stiffening till they are ready for the press.

HACK-BOARDS AND TILES.

In damp situations the hacks are liable to remain damp for long periods so that an earth bed without other covering will not allow the bottom row of bricks to dry satisfactorily. *Hack-boards* or *hack-tiles* are then employed, with advantage, on

which to set the blades of bricks. Hack-boards are made in long lengths, two boards 5 or 6 inches in width and from 1 to 1½ inches in thickness, being held together edge to edge by transverse ledges 3 inches wide and 2 inches thick at suitable intervals (Fig. 12).

FIG. 12.

Hack-tiles present distinct advantages over hack-boards, in that they are cheaper when home-made, are imperishable and do not require removal in winter. They can be made in an ordinary pipe machine in 12in. lengths, tubular, and 4½in. by 2½in. in rectangular section (Fig. 13).

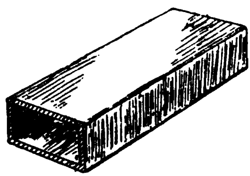


FIG. 13.

If home-made and a little irregular it is well to spread a thin layer of sand on hack-tiles before setting the bricks on them. When drying common drain-pipes on hacks, nothing is better than a row of burnt pipes of the same diameter placed in a similar manner on the hack. Hack-boards or tiles allow a passage for air underneath the blades of bricks so that damp air is not so liable to stagnate against the ground, and moisture is not drawn up from the ground by the brick.

ERECTED HACK ROOFING.

On permanent hack grounds it is frequently customary to fix the hack covering on posts at a given height above the ground. The roofing material may then be straw or wood as for portable hack covers, and in many yards common pantiles are in use. This last form has not much to recommend it, as the

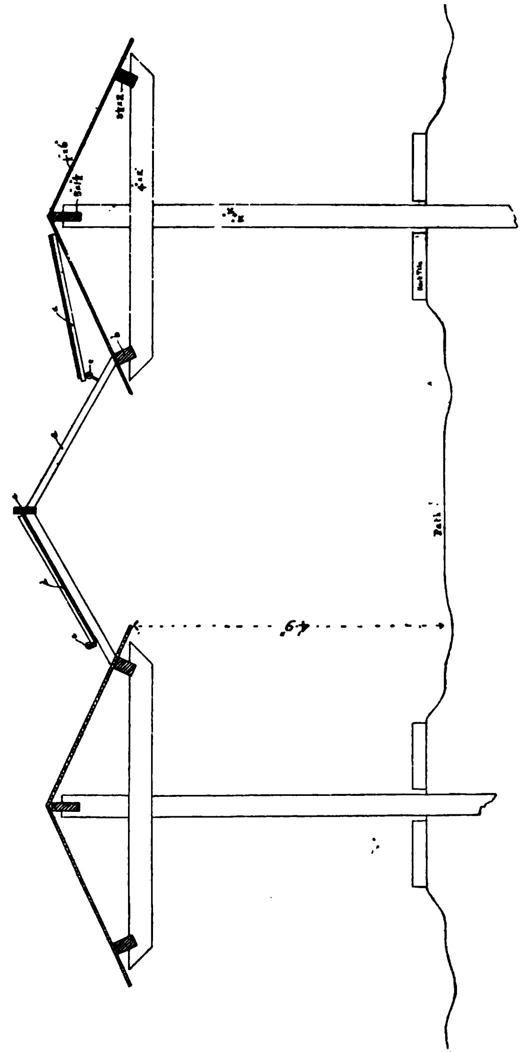


FIG. 14.

tiles are heavy and require adequate strength in the posts, framing and rips to support them. Preference should certainly be given to boarding about ¾in. thick, which may be supported on framing as shewn in Fig. 14, the posts being placed 10 feet apart along the centre of the hack.

Erected hack roofing is best arranged with the hacks spaced about 9ft. apart from centre to centre. It is usual to board up both ends of each hack closely and the full width of the roofing. For the protection of the sides of such hacks against wind, sun and rain, loo-boards or mats may be used. There are many ingenious arrangements in use for the protection of bricks under erected hack-roofing. Mechanical devices have been introduced for raising or lowering the roofing itself and for performing similar operations with side shutters. These devices are, however, as a rule, expensive to erect and unsatisfactory in work. In consequence of long exposure to weather they are likely to become greatly deteriorated.

One of the simplest and most efficient methods is shewn in Fig. 14. A series of short rafters *a*, 2ft. 6in. by 3in. by 1¾in. and 5ft. apart, are nailed at one end to the hack roof purlin *b*, and at the other to a light ridge *c*, 4in. by 1in., which is continuous throughout the length of the hack. Shutters *d*, hinged at *e*, rest on the rafters on both sides of the ridge when closed, with a narrow space for ventilation between their lower edges and the hack roof. Each shutter is made up of five boards, 5ft. by 5½in. by ¾in., held together by three ledges, 2ft. 3in. by 1¾in. by 1in. In order to be able to take off and store these shutters in winter the hinge is made up of two screw eyes, and a pin as shewn in Fig. 15 in detail. A pin

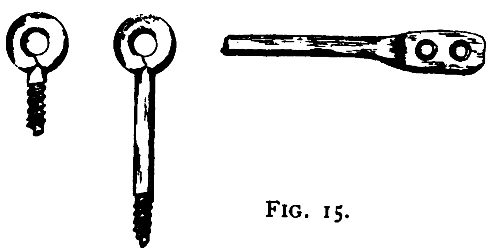


FIG. 15.

is screwed to one end of a shutter and a short screw eye to the other. The long screw eye is screwed into the rafter. On putting the pin through the screw eye in the rafter, and the screw eye on the next shutter, a complete hinge is formed. These shutters may be easily manipulated according to necessity, either or both sides being open or closed. During storms when the shutters are closed the greater part of the rain drips off the shutters on to the hack roofing, and thence to the drainage trenches on both sides of the hacks. Driving rain, strong wind, and sunshine are completely and easily baffled from any direction. A hack ground equipped in this way provides very efficient protection to the bricks to be dried and ample ventilation. At the same time, the bricks are not damaged by contact with the covering or the side protection.

Other Forms of Hack Roofing.

Two more forms of erected hack roofing should be mentioned before leaving this part of the subject. The construction illustrated in Fig. 16 is very convenient for covering bricks which do not easily crack and warp if dried quickly. The roofing is higher from the ground and consequently admits of more ventilation than that previously described. At the same time the form of framing renders the whole more rigid, and less dependent on the strength and soundness of the individual posts. Loose boards braced together in 10 or 12ft. lengths, 2ft. wide, which may be shifted as desired to either side of the gangway, give a means of protecting the bricks against driving rains.

Continental authorities recommend the use of racks covered singly with roofing as shown in Fig 17, or in pairs ; the gangway between the racks in a pair being under cover. The chief advantage claimed for such arrangements lies in the fact that the bottom rack is placed higher above the ground, and the lowest row of bricks is better and more quickly dried than is possible with the usual method of hack setting. It is stated that a brick will dry at a height of 9ft. above the ground level in half the time it will when set on the ground.

It is doubtful whether this system can really be recommended for out-of-door drying, in consequence of the great extra cost of

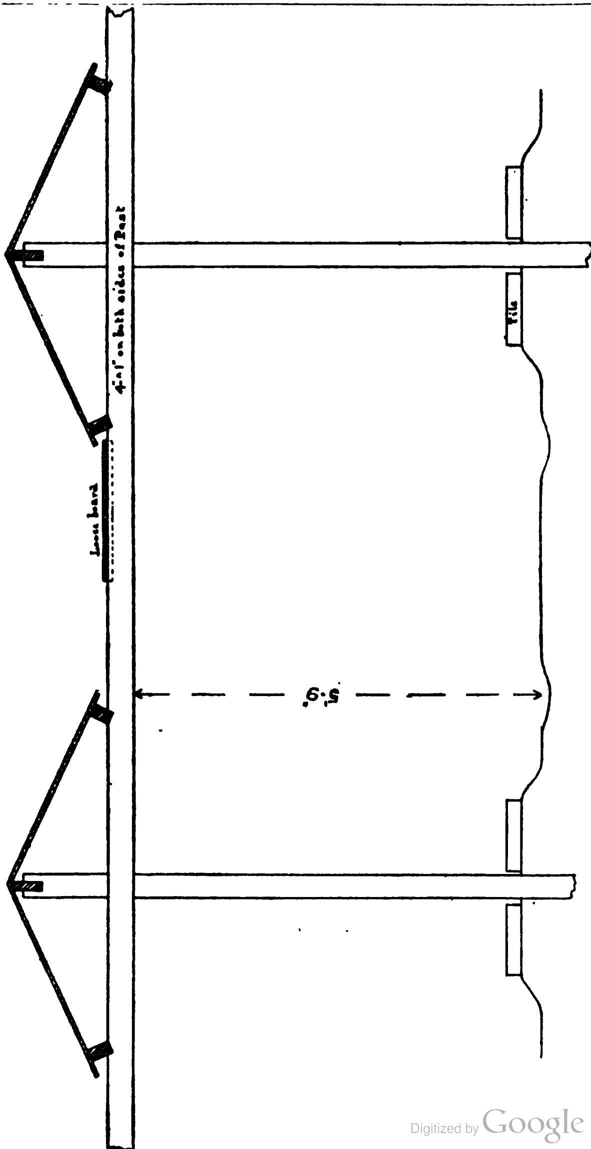


FIG. 16.

construction, and also because the bricks would require much protection and watching to keep them from drying too rapidly.

It is a system which may be adopted to advantage under large shed roofing, where a better class of brick is made, and where no special means are necessary for the protection of the individual racks against wind, sun and storm.

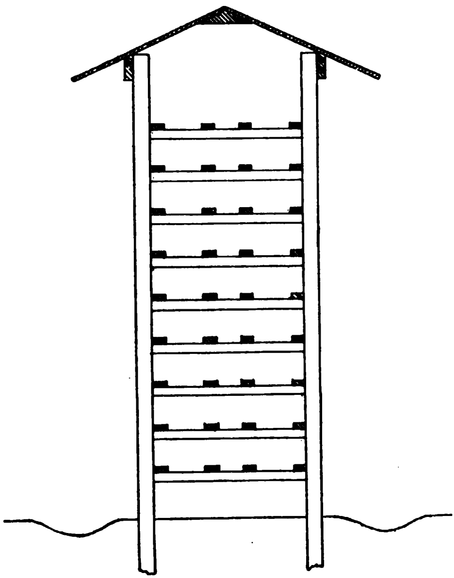


FIG. 17.

FROST.

Before quitting the subject of out-door drying, a word is necessary on the subject of frost. The season for out-door drying is restricted, by the consideration of danger of freezing, within narrower limits than would be imposed solely by the question of the drying capacity of the air. March winds are proverbial, and fine weather often entices the brickmaker into an early commencement of out-door making; yet both in March and April severe frosts sometimes occur, which would destroy newly-made bricks exposed on hacks. Similarly in the latter

half of October, and early in November, fine weather is frequent enough to make the brick manufacturer regret that he has not prolonged his making season by a week or more. Yet, in the usual way, he dare not do so, for fear of unexpected frosts.

Forecasting Night Frosts.

There is, however, a way of forecasting the occurrence of a night frost, in the course of the preceding afternoon, which if more commonly known and practised, would enable brickmakers to take precautionary measures, in time to save their bricks from its effects. One may even foretell the mean temperature of the following day by the same means, an hour before sunset.

The only instrument required is the "wet and dry bulb thermometer," illustrated on page 4 (Fig. 1). It has been established by a long and careful series of observations, that the reading of the *wet bulb* thermometer *in the shade* between two and three in the afternoon exceeds the lowest air temperature of the succeeding night by 7½ degrees Fahr. One has, therefore, only to take the wet bulb reading at that time, and deduct from it seven degrees, and if the resulting figure is less than 32 deg. there will certainly be a frost during the night. Similarly the reading of the wet bulb thermometer one hour before sunset will give the air temperature at eight o'clock on the following morning, which corresponds approximately to the mean for the day. It is necessary to keep the apparatus in good working order by occasional washing of the wet bulb covering and wick, and it is also essential to place the thermometer in the shade and in a place where warm buildings cannot influence its readings by radiation. The reading given by the thermometer with the uncovered or dry bulb is not of any import in these forecasts.

This rule is absolutely reliable on the Continent, but is naturally not quite so certain on our Island, because of the proximity of the sea, and the sudden changes of wind. Nevertheless, it is of great value, and is well worthy of the attention of makers who are anxious to use every available day of the year for out-of-door brickmaking.

Working Cost of Hack Drying.

All the appliances described above, are the outcome of many years' practice, in the endeavour to contend against the vagaries of the weather, so that no expenditure should be incurred in the consumption of fuel for drying. The working cost of drying bricks is thus confined to the cost of labour and repairs. It will be interesting in the course of this treatise to make careful comparisons between the various systems described, with a view to ascertaining which is ultimately the most economical form of drying to adopt in brickmaking.

It will be seen that the cost of equipping a hack ground for an output of a million bricks yearly, is from £150 to £250, according to the completeness of the installation.

The repair bill for the same ground is rarely less than £25 per annum, when the cost of labour in the spring involved in preparing and clearing up the ground, and that in clearing up and storing the material in the autumn is considered. The loss from damage to bricks by weather and rough treatment on hacks is difficult to assess, but it is always considerable, even in the most carefully managed yards, and cannot be put at less than 5 per cent. on the make, or say, 4d. per thousand.

The labour of wheeling bricks to the hacks, hack-setting, skintling, looing, and general attendance, and finally wheeling to the kiln when dry, costs upwards of 2/6 per 1,000.

Taking, therefore, all into account, the cost between the machine or mould and the kiln cannot be put at less than 3/3 to 3/6 per 1,000. This may be considered as the amount actually expended on drying common bricks on hacks, and is the figure which must be carefully verified by each particular maker, when comparing the system with others.

Drying Sheds.

The next step in the evolution of drying systems is the erection of sheds of more or less considerable extent. The sheds themselves may be simple structures in wood or in brick, roofed with tarred felt, tiles, slates or galvanized corrugated iron. It is necessary to provide adjustable appliances for ventilation, in order to carry off the moisture dried out of the bricks.

Beneath this protection, the bricks may be set in longitudinal or transverse hacks, but if the brick is of a quality common enough for this method of treatment, it is at once cheaper in first cost, and more efficient in rapidity of drying, to use the out-door hacks already described.

Bricks may be efficiently dried if set in rows on an evenly sanded floor, but this method, without artificial heat, does not give an adequate output.

The only system which is practically efficient without artificial heat is that of setting the bricks in racks.

Racks may be placed longitudinally or transversely in the shed. The ventilation of a shed is, however, transverse, and it is much better to place the racks transversely. It may be urged that it is surely better to pass the air for ventilation through the racks of bricks rather than between them. It will be readily understood, however, that with natural aëration, the currents of air are usually but feeble, and the first rack will considerably reduce their power. The rack next the direction of the current too, is exposed too openly to its effects, and is dried too quickly, and further, when the current has passed through one or two racks, the air is so heavily charged with moisture that it is no longer of value for drying. In the use of transverse racks, on the other hand, the bricks are not directly exposed to the sharp currents of air, which, sweeping unretarded through the gangways, carry off the moisture diffused out of the bricks.

The transverse rack system is practically the only one used on the Continent, and is minutely described by the German authorities on brick making, not only because of its use in simple unwarmed sheds, but also because of its wide adoption in buildings covering Hoffmann kilns.

A simple unwarmed shed may be 36ft. wide and 150ft. long inside, with a gangway 6ft. wide down the middle.

The illustration (Fig. 18) of such shed, in cross section, shows a galvanized corrugated iron roof (*a*) with ½in. matchboard lining (*b*). The posts (*c*) and principals (*d* may be 10ft. apart to suit the racks, and the purlins (*e*) complete the roof framing.

The sides may be fitted with a double row of hanging

shutters, or with adjustable Venetian shutters (*f*); or again, brick walls may be built to carry the roof with a series of windows, and rows of perforations in the brickwork. Ventila-

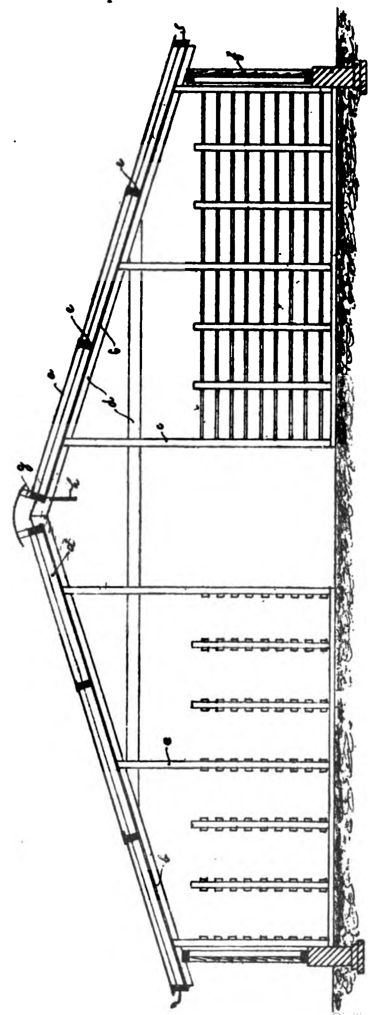


FIG. 18.

tion is also provided for at the ridge (*g*) by setting it a couple of inches above the roofing.

An adjustable row of shutters 5ft. long, may be provided to close this space, as shown at (*h*). Fig. 19 is a part plan of the shed.

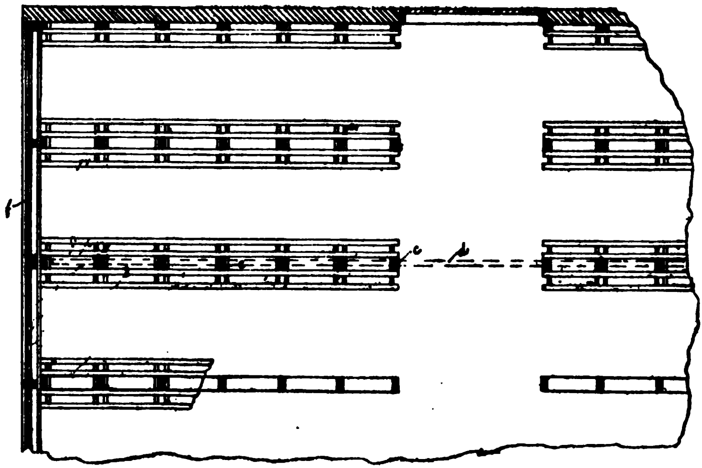


FIG. 19.

The simplest Venetian shutter is constructed of horizontal slats 5ft. long, pivoted at both ends at (*a*)—Figs. 20 and 21—a vertical bar (*b*) with handle (*c*) is pivoted at the middle of the shutter, and is provided with pegs (*d*) corresponding to the slats. By turning this vertical bar through an angle of 90° each peg opens the corresponding slat. Fig. 20 shows the shutter in vertical section and part plan shut, and Fig. 21 shows it open. This is the form of side ventilation usually adopted on the Continent.

The racks are 15ft. long, with gangways 3ft. wide between them. Each is constructed 2ft. in width, to hold two rows of bricks on each stage, and the supporting posts may be from 2ft. 1in. to 3ft. 6in. apart. If the bottom stage is only 6in.

above the floor, the rack may have nine of them in height, within the workmen's reach.

It is not advisable, on account of the cost of labour, to place bricks higher from the ground than this, though in some

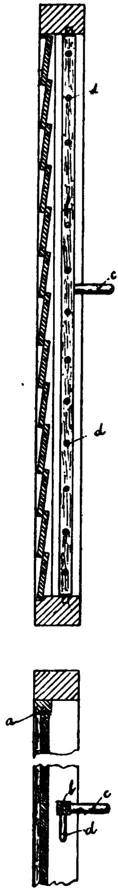


FIG. 20.

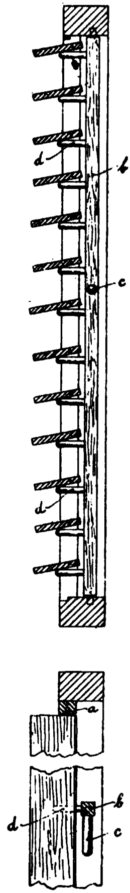


FIG. 21.

systems the sheds are racked close up to the ceiling on each side of and over the main central gangway. Generally speaking, the rack construction costs a sufficiently large proportion of the total cost of the shed for it to be advisable to keep it low enough to be worked without trestles or ladders.

Multiplication of racks, too, will result in the accumulation of too much moisture in the air of the shed except in windy weather.

The fact that so much space in the roof seems unused tempts one to think that an economy can be realised by occupying it with racks. This, however, is a fallacy, which a short experience will rapidly demonstrate.

On the Continent, it is very largely the custom to cut bricks at the machine in pairs, instead of as many as ten at once as is usual in England. The shed racks are then provided with four slats to each stage, two for each row of bricks. The pairs of bricks are set on these slats on pallet boards. Stout wires sometimes replace the slats either completely or in alternation.

This method of cutting off in pairs has some advantages, for the bricks do not need spacing in order to dry them, the space between the pairs being sufficient. The labour of cutting off, too, is lighter, though more continuous. In this country slats may be similarly provided for hand-made bricks placed on pallets, but there is much to be said for the use of loose boards of convenient length, which may be slipped into the racks on fillets, nailed to both sides of the supporting posts. Boards 2ft. 4in. in length will hold seven spaced bricks on edge, and are of a very convenient length for shed work. They will hold five bricks flat. The supporting fillets should be 7in. from the top of one stage to the top of the next, and the topmost one will then be 5ft. 2in. from the ground. The arrangement of posts and fillets for the reception of boards in this way is shown in Fig. 18 on the left-hand rack. Fixed slats are shown on the right-hand side, and in Fig. 19 on plan.

The contents of one rack 15ft. long will then be :—

Stages.	Wide.	Long.	Bricks.	
9	2	6	7	= 756 bricks.

A shed 150ft. by 36ft. will contain 60 of these racks, giving a

total capacity of 45,360 bricks. Allowing three weeks to dry bricks in it, the output is 15,120 per week, and without artificial heat, a yearly output not exceeding 350,000.

Three sheds will, therefore, be required to give the same output as a hack ground of one acre in extent.

If hand-made bricks are placed in the racks flat, and on pallets, the contents of the sheds are reduced by two-sevenths, unless the racks are provided specially with stages closer together. It is really preferable to pitch the bricks on edge on boards, which carry seven bricks each, and may be placed in the racks.

If the clay is liable to crack in quick drying, racks may be constructed in the middle of the shed with a gangway 4ft. wide down each side. In this arrangement the wind does not come so sharply in contact with the bricks nearest the outside.

Cost of Sheds.

Taken roughly, the cost of constructing such sheds is £1 per foot run; or £150 for a shed without the racks.

The racks themselves, including boards, on to which the bricks may be cut by the machine, will cost about £2 each, or £120. Total cost of shed £270, or for an output of one million yearly without artificial heat, £810. It is evident that this method of protection is much more costly to install than hack roofing.

Cost of Labour.

As a set-off against this, the labour is less; the distance from the machine to the racks, and from the racks to the kiln, is on the average, only one-third, and there is no skintling to be done. The repairs also are insignificant, and there is no preparation required in spring, or storing away of material in winter. The waste by weather and rough treatment should be *nil*. Taking all these points into consideration, the cost of drying bricks as compared with the figure arrived at for hack drying, is from 2/3 to 2/6 per 1,000. But there is a charge to add for additional interest on capital of about 7d. per 1,000.

Tile Drying.

Although not in the strict sense "bricks," some mention must be made here of the drying of roofing tiles,

Being manufactured of strong tenacious clays, the operation of drying must be conducted slowly, with great care taken to avoid air currents. They must be dried in sheds, and the form last described is in every way suitable for the purpose. It is necessary, of course, to modify the dimensions of the racks to suit the dimensions of the goods, and the slats or boards should be spaced less widely apart, quite double the number in height being provided.

In the placing of pan-tiles or French tiles in the racks, it is usual to make use of loose strips of wood to give support to the surface lying hollow over the slats, to prevent it collapsing while in a soft state. Trimming, beating or pressing may be had recourse to when the tile is partly dried, after which it is again replaced in the rack till ready for the kiln.

In the drying of plain tiles recourse is had, in most manufactories, to checkering. Being thin, they are extremely liable to warp as well as to crack if dried too quickly. The "checker" is the means adopted to prevent both these defects.

In a portion of the shed unprovided with racks are placed boards as wide as the tiles are long. They are curved convexly in transverse section, so that when tiles are laid on them in a soft condition they take the curve suitable for the requirements of this form of tile. The stiffened tiles after beating or pressing are placed in thicknesses of three or four flat across the boards, their edges nearly or quite touching. On the first row a second is placed, breaking joint, and similarly to a height of about four feet.

The solid checker of tiles so stacked ensures slow drying, and the perfect retention of the required shape.

CHAPTER III.

ARTIFICIAL DRYING.

The next advance in the evolution of brick-drying systems leads into the second main division of the subject, "Drying by smaller volume of air at artificially increased temperature."

It is the most important division of the subject, for the manifold advantages of having the drying process under control are evident, and it can be shown that these advantages really out-weigh the disadvantage of the expense of fuel. It is the more intricate division of the subject, because of the different conditions under which heat may be applied to drying and the necessity for obtaining the greatest possible efficiency from the fuel or source of heat employed.

The problem in itself seems simple, for one is apt to assume that the mere warming, say, of a shed, some 10° to 20° above the outside temperature would ensure rapid and effectual drying of the bricks, and would not require much fuel. Scientific calculation, however, throws unexpected light upon the subject, and shows the necessity for great care in the arrangement of artificial systems and for great caution in accepting the statements of interested persons as to the fuel consumed in known systems.

Scientific Principles Reiterated.

In consequence of the importance of the chief fundamental facts, it is necessary to emphasise here the statement made (page 1) that no drying can be obtained without absorption of heat. If hot air is passed slowly over a dry cold brick it will be only slightly cooled, but if it is passed over a very wet brick, it will be considerably cooled.

To raise a dry brick weighing 7lbs. from 60° to 61° F. takes only 1·4 units of heat, but to raise in the same way the temperature of a wet brick weighing 7½lbs. and to evaporate at the same time the ½lb. of water it contains, will take 537 units of heat, or nearly 400 times as much. The latter figure represents the heat yielded by the consumption of about ¾oz. of ordinary coal. Not only so, but the heat has *absolutely disappeared*, and can only be recovered by condensing the vapour of the water back into water again.

For this reason the statements which are sometimes made, that certain drying systems use heat over and over again, and that the heat is not allowed to escape, must not for one moment be credited, although at first sight they may seem to be borne out by the system referred to.

It is also very necessary to call attention again to the statements on page 2, of the peculiar property of air of carrying moisture in amount varying with the temperature. The table there given shows that air at 82° F. will carry double the quantity of moisture which it will carry at 62° F. Its carrying power is approximately doubled for a rise of 20°. Nevertheless, when once the air at a given temperature is carrying its full complement of moisture, and is saturated, the fact that it feels warm, and is kept warm, does not imply that further drying of bricks contained in it will ensue. It is saturated, and cannot take up more moisture, and it is now necessary to carry off this saturated air by ventilation, and replace it by more warm air which is not saturated.

It is by a careful adjustment of the temperature and volume of air supplied to a dryer that the most efficient results are obtained, and it is a knowledge of the scientific principles involved that enables the expert to ensure these results.

Method of Heating.

It being demonstrated that to effect drying by artificial means it is invariably essential to provide adequate ventilation and that the ventilation must be effected by means of air warmed above the average temperature of the air outside the dryer, it remains yet to mention two means by which the necessary heat for drying may be provided other than by the warmed air itself. The three methods thus forming the sub-divisions of artificial drying may be thus stated :—

1. By heat supplied by convection, *i.e.*, by warmed air which is reduced in temperature, and renewed or partly re-heated, when charged with moisture.

2. By heat supplied by conduction, *i.e.*, by contact of the goods with the source of heat supply, air only slightly warmed being supplied to carry off the moisture.

3. By heat supplied by radiation from the source of supply, air warmed to a moderate temperature being supplied to carry off moisture.

The second method was the earliest adopted in practice, a combination of the second and first being next developed, while

the first and third separately and in combination are those now most in vogue with varying degrees of success according to the intelligence displayed in adapting them to individual cases. It may be broadly stated that the third by itself or in combination with the first produces the most efficient and successful results and the general tendency of recent improvements in dryers is towards an unscientific or "Rule of Thumb" application of it. The results arrived at by long and expensive practical experiments might have been long since obtained, if science, in its technical form, had been earlier applied to the solution of the problem.

Strictly speaking, the *simplest* procedure is the method of supplying warmed air, which yields the requisite heat for evaporation, and at the same time serves to carry away the moisture.

It is the process which plays the principal part in outdoor natural drying, and though not first in order of practical application to artificial systems should be discussed first.

Drying by Warmed Air.

In the description of the science of outdoor drying, a calculation was given shewing how air, at ordinary temperatures, can supply sufficient heat to effect the evaporation and without sensible reduction in temperature (page 5). In artificial drying, the conditions are so altered that further calculations become necessary to demonstrate the process.

Air at outside temperatures is introduced into the dryer warmed, so that it will take up a certain quantity of moisture. In causing the evaporation from the goods, it becomes cooled to an intermediate temperature, and leaves the dryer more or less charged with moisture. On page 3 a table was given shewing the amount of air necessary at various temperatures to carry 1lb. of water in vapour. Now it is necessary to calculate to what higher temperatures it must be warmed in order to yield the heat necessary to evaporate the 1lb. of water out of a brick.

Outside air contains always some moisture, and as a basis for calculation it may be assumed that it is saturated and at 32° F.

A first case may be calculated in which the air is warmed to 72°, and after doing its work leaves the dryer cooled to 52°.

The weight of air which will yield sufficient heat to evaporate 1 lb. of water in cooling from 72° to 52° is given by:—

$$\frac{{}^{*}1078}{20 \times \cdot 237} = 227 \cdot 27 \text{ lbs.}$$

and the heat necessary to raise this quantity of air from 32° to 72° is given by:—

$$227 \cdot 27 \times \cdot 237 \times 40 = 2{,}156 \text{ British Thermal Units.}$$

This is the actual heat needed for the evaporation only, without reference to the warming up of the clay of the bricks and other losses.

Under the temperatures here given the air if saturated with moisture at 32° will, after warming to 72°, evaporation of 1lb. of water and cooling to 52°, issue from the dryer again saturated, carrying now 1·86 lbs. of water.

Similar calculations for other temperatures give the results tabulated below:—

TABLE IV.

Temperature of air entering dryer.	Temperature leaving dryer.	Weight of air required.	Heat required to dry 1lb. of water in B.T.U.
72 degrees.	52 degrees.	227·27	2156
98 ,,	62 ,,	125·00	1954
130 ,,	72 ,,	77·00	1788
170 ,,	82 ,,	50·50	1652
220 ,,	92 ,,	34·50	1537

In practice the actual heat required as shewn in this table must be augmented by 50 to 100 per cent. to allow for the heating of the dryer walls, loss by radiation and warming of the clay in the bricks.

In practice, also, it is not possible to attain saturation of the air leaving the dryer.

The table serves to indicate, however, that if a clay will stand high temperatures and rapid drying, it is most economical to use a small volume of air, with large range of temperature. Thus, in practice, the table would indicate that, with all necessary

* Latent heat of evaporation at 52° F.

allowances, 1,000 bricks containing 1 lb. each of water of manufacture, will require the following amounts of heat (with their coal equivalents) to dry them :—

TABLE V.

Temperature range.	Volume of air per brick, in cubic ft.	Heat in B. T. U. per thousand.	Coal in cwts. per thousand.
72 deg. to 52 deg.	4500	3,240,000	2·4
98 ,, to 62 ,,	2750	3,100,000	2·3
130 ,, to 72 ,,	1950	3,000,000	2·2
162 ,, to 82 ,,	1450	2,850,000	2·1
220 ,, to 92 ,,	1120		

It is necessary, of course, to note that the amount of heat and fuel will be less if the outer air is warmer than 32° and is not saturated with moisture.

The actual fuel consumption also may be less, according as the dryer is more efficient, the loss in the calculations, in Table V., being put at 50, 60, 70, 80, and 90 per cent. respectively.

VENTILATION.

The higher the temperatures employed, the more necessary it becomes to pay attention to the means of effecting the necessary movement of air in the dryer.

In the employment of low temperatures, simple aëration is customary, and provision for ventilation such as described in connection with Fig. 18 (page 34) is sufficient.

In such cases, a large quantity of heat is lost, and in drying by warm air, it is better to have recourse to chimneys or fans.

VENTILATING CHIMNEYS.

In the use of a chimney, it is essential that the air which issues by it, should be at a temperature higher than that of the outside air.

Systems using such chimneys will be described later in detail. It is only proposed at this point to indicate the draught that may be obtained by such means.

In such a case as before mentioned, when the air outside the dryer is at 32°, when the air enters the dryer warmed to 72°

and issues at a temperature of 52° ; the velocity of draught in a chimney 30 feet high, is calculated by the formula :—

$$* \ v = \sqrt{\frac{2 \times 32{\cdot}2 \times {\cdot}002\,(52^\circ - 32^\circ)\,30}{1 \times {\cdot}002\,(32^\circ - 32^\circ)}}$$

8·8 ft. per second
or 528 ft. per minute.

This value must be diminished by a proportion depending on the amount of friction and the eddies in the chimney, and we do not in practice find such conditions yield a velocity exceeding one-half or say, 250 ft. per minute. Now it was shewn in Table V. that 4,500 cubic feet of air at 72° are required to dry 1 lb. of water out of a brick. This is equivalent to 4,332 cubic feet at 52°.

Hence it follows that in order to remove 1 lb. of water per minute from a dryer, under the above conditions, it would be necessary to construct a chimney of about 17⅓ square feet cross section (4ft. 2in. × 4ft. 2in.) and 30ft. in height. Such a combination would result in the drying of 10,000 bricks in a week, provided all the theoretical conditions were fulfilled. In practice it is found that chimneys of large section will produce a good ventilation if upwards of 40ft. in height, with a difference of temperature only of 8° or 10° between the outer air and the air leaving the dryer.

VENTILATING FANS.

Power-driven fans become more or less necessary when higher temperatures are employed and when the output of a dryer is intended to be rapid and large. Selecting the range of temperature from 162° to 82° given in Table V., the volume of air practically required to dry 1 lb. of water out of a brick is shewn to be about 1,450 cubic feet.

A dryer, therefore, to turn out 5,000 bricks (each containing 1 lb. of water) per day would need to be supplied with about 5,000 cubic feet of air per minute at 162°.

Now the previous calculation on chimney draught would

*32·2 is the force of gravity in feet per second, and ·002 is the expansion of air for each degree.

seem to shew that a chimney of good height and area would be capable of producing the required draught, but a difficulty is met with which renders it quite unsuitable.

In consequence of the reduced volume of air employed, it is necessary to ensure its continual close contact with the goods to be dried. It is also necessary, in order to obtain full reduction of temperature, to arrange the goods in long tunnels, and to dry them progressively.

The consequence of this form of arrangement is the creation of a considerable amount of resistance to the passage of the air, such as a chimney cannot overcome.

By mechanical means, not only can the resistance be conquered, but the air supply can be kept under complete control, and efficient arrangements can be made for heating it to the required temperature. The draught also is quite independent of the external temperature, and other atmospheric conditions.

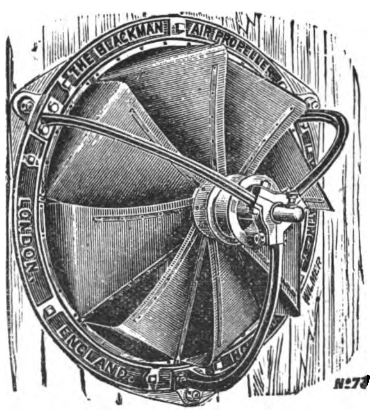


FIG. 22.

Fig. 22 shews a Blackman fan of a type so well known that a detailed description of it is unnecessary.

Table VI. gives figures indicating the performance of various sizes.

Table VI.

Diameter of blades in inches.	Revolutions per minute.	*APPROXIMATE	
		Cubic feet of air moved per minute.	Actual h.p. required.
14	1,000 to 1,500	1,000 to 1,500	⅛ to ¼
24	500 ,, 900	3,000 ,, 6,000	¼ ,, ¾
36	400 ,, 650	7,700 ,, 14,000	½ ,, 1½
48	300 ,, 550	13,500 ,, 30,000	1 ,, 2½
60	240 ,, 400	21,000 ,, 45,000	1½ ,, 3½
72	200 ,, 340	30,000 ,, 60,000	2 ,, 5

This type of "ventilating" fan is suitable for moving large volumes of air at low velocity against small resistance and cannot be efficiently used against a resistance of more than three-eighths of an inch of water, or one-fifth of an ounce per square inch. A ventilating chimney cannot overcome nearly so much resistance even as this.

The Blackman fan is probably the pioneer of this type in England, but there are many other makers, such as the Sturtevant Company, the American Blower Company, the Sun Fan Company, and others. There is naturally considerable controversy as to the respective efficiencies of the different makes, but the actual tests are extremely difficult to make with certainty, and the statements of the makers must always be accepted with some reserve.

The chief scientific points of the method of drying by warmed air alone have been indicated above, and further calculations are only necessary in connection with the individual systems, which will be described later. Since the other methods of drying by conduction and radiation are always more complicated from a scientific point of view, it will be best to proceed now to the description of the various forms of dryers and to discuss their efficiency from a technical standpoint individually.

* These figures apply to "free inlet and outlet," at least equal in area to the fan itself throughout. The volume moved is reduced, and the power required is increased by any further resistance to be overcome by the fans.

CHAPTER IV.

CLASSIFICATION OF DRYERS.

The sub-division of dryers into groups does not follow the same lines as that of methods of drying. They may be classed as follows :—

1. *Dryers warmed and aërated*:
   - *a.* Those placed above and about kilns, utilising the waste heat of radiation and burned brick cooling.
   - *b.* Those furnished with flues in the floor heated by waste heat from kilns, coke fires, or steam.
   - *c.* Those provided with flues or pipes detached from the floor, similarly heated by waste heat, coke fires or steam, and also by hot water.
2. *Dryers warmed and ventilated with the goods stationary* :
   - *a.* Those placed over or against kilns with special appliances for controlling the air currents.
   - *b.* Those furnished with heating flues and ventilating chimneys.
   - *c.* Those provided with detached heaters and ventilating chimneys or fans.
   - *d.* Those with isolated chambers or tunnels, ventilated and used intermittently.
3. *Dryers warmed and ventilated with the goods moving and drying progressively* :
   - *a.* Those ventilated in the reverse direction to that in which the goods move.
   - *b.* Those ventilated in the same direction as that in which the goods move.

This classification is, to a large extent, stated in historical sequence as well as in the order of efficiency of heat consumption. The description of dryers will follow the order as closely as possible, though in some few instances it is not easy to define exactly to which category they belong.

I.—DRYERS WARMED AND AËRATED.

The word "aërated" is used in contrast to "ventilated" simply indicating that the moist air which is carrying off the water dried out of the goods is not conducted out of the dryer by any special ventilating appliance. It may escape by windows, doors, shutters or roof openings, and may be said practically to diffuse into the external air.

a. *Dryers placed above and about kilns utilising the waste heat of radiation and burned brick cooling.*

The photograph—Fig. 23—shews perhaps the oldest kind of dryer in which this practice was followed.

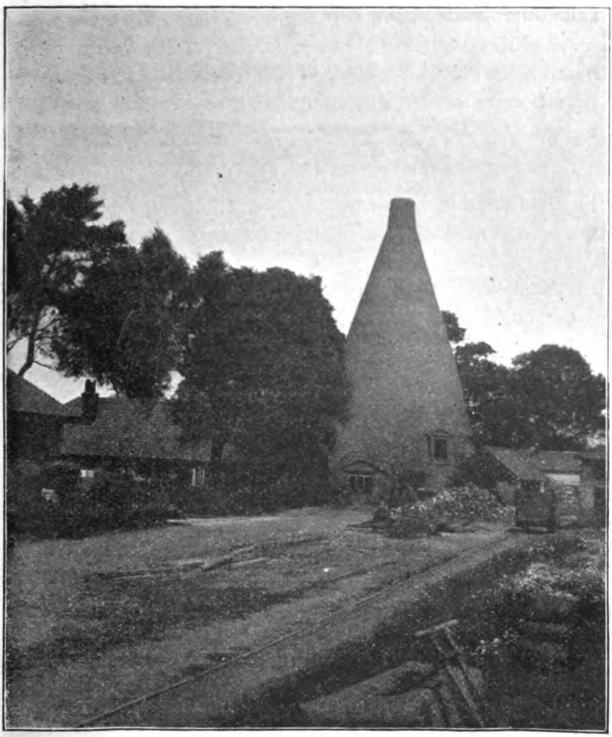


FIG. 23.

These kilns were used by common pottery makers and contained, well within the base, an open top kiln of the Dutch form, above which were arranged one or more drying stages or floors. The photograph is taken from one existing at Upminster in Essex, which was built in 1774. It is 60ft. or 70ft. in height and the brickwork at the base is 3ft. in thickness. Holes in the interior still shew where the joists were fixed, which supported the drying floors. Common red pottery appears to have been made in it only, and the original kiln in the interior has long since been replaced.

Similar use of the heat from kilns is made in potteries in these days, but with the difference that it is the heat radiated from the outer walls of the kiln.

The products of combustion are carried out above the roof of the building inside which the kiln is constructed. In this system the radiation method of supplying heat to the goods is chiefly used.

Hoffmann Kilns.

The chief form in which waste heat is made use of under this section is in connection with continuous kilns of the Hoffmann type.

In some instances, the flat top of the kiln is used, simply by setting bricks on it in hack form. Almost the whole top can be so utilised, it being necessary only to provide a gangway and to leave sufficient room for the coal above the chambers where the firing is in process.

In Germany, there are many installations in which drying is effected in immense buildings erected over Hoffmann kilns. In most of these there is a special provision for directing the air currents. They, therefore, belong to section **2a** of the subdivision, and will be mentioned later.

The manner in which such buildings are constructed is shewn in cross-section in Fig. 24. It is evident that they are very costly, and that the labour involved in raising goods to the racks and lowering them when dry is very great.

On the Continent labour is cheap, perhaps on an average only half the cost of it in England, and this consideration is not of

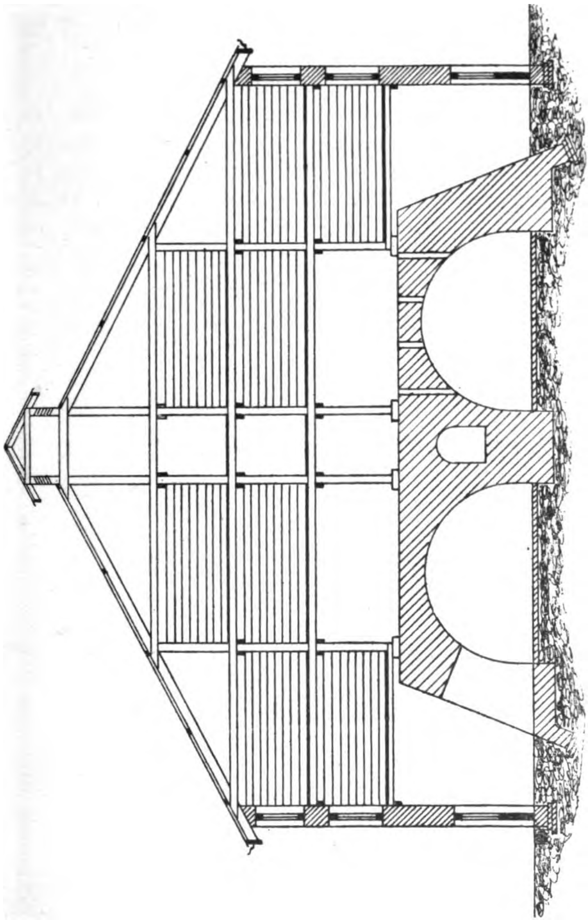


FIG. 24

such importance as with us. Nevertheless, an arrangement such as this has but little to recommend it, as it can only be used with safety during nine or ten months of the year. Its drying efficiency is greatly influenced by the weather, and during winter there is danger of freezing in some portions of the

building, in spite of the heat radiated and carried up by the air from the body of the kiln.

Otto Bock's Kiln.

To shew the importance attached in Germany to the employment of waste heat from continuous kilns, a description follows of the invention of Otto Bock, a well-known brick-works engineer of Berlin. It is designed for a moderate output of five to ten thousand bricks per day. Figs. 25 and 26

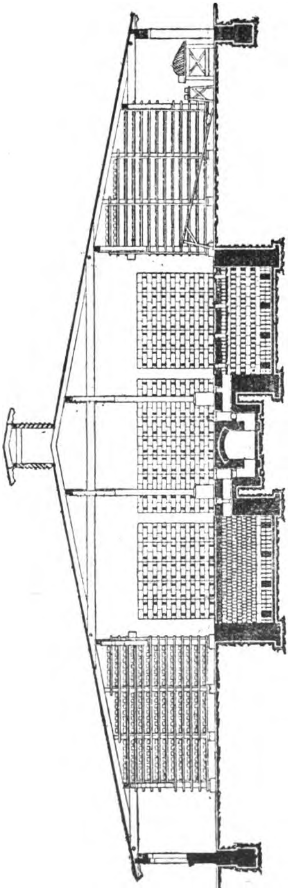


Fig. 25.

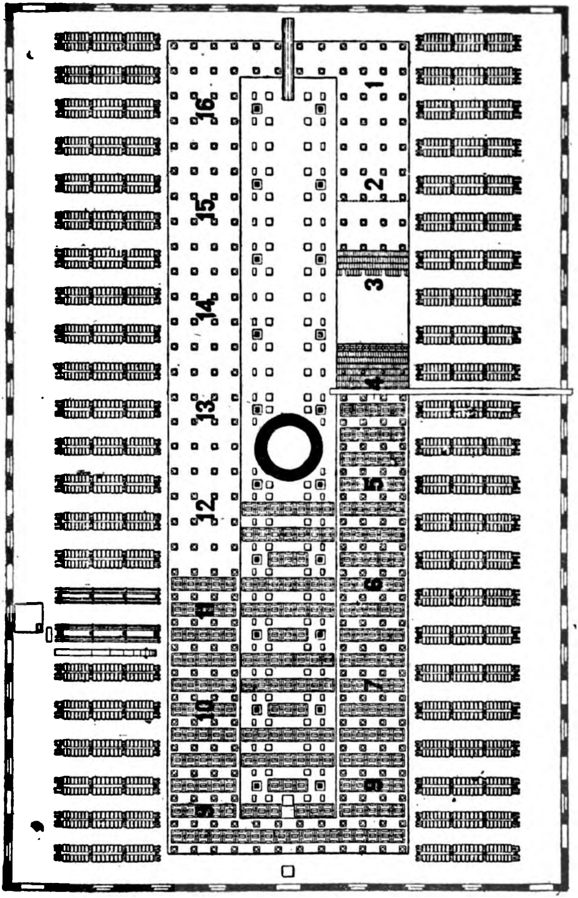


FIG. 26.

shew the entire construction, of which in reality the chief novelty is the kiln without arch, provided with certain advance drying and smoke flues, which need not be described here.

The kiln is only about four feet deep, and is sunk in the ground so that when full of goods, the covering courses are level with it. On each side of the kiln are racks, and the whole

is covered with one large roof. The drying and the burning are intended to be synchronous, so that labour may be reduced to a minimum; ordinary aëration only is provided for.

In Fig. 26 the moulding table is shewn adjacent to the 11th chamber. The newly-made bricks are placed in the nearest racks, which have just been cleared of others partly dry. As the racks are filled the table is moved along adjacent to other empty ones. When partly dried, the bricks are piled on the kiln itself, on the covering course of the chambers, and over the central flue. They are so placed just after the full fire has passed, so that the top of the kiln is no longer occupied by the coal and the burners.

By the time the fire has advanced, and the chamber beneath them is cool enough to be drawn, the bricks are dry, and may be simply dropped down and set at once for burning.

In Fig. 26, chamber No. 3 is being set, and No. 4 drawn Nos. 5 to 8 are cooling, 9 to 11 still red-hot, 12 to 14 in full fire. 15 and 16 getting hot, and 1 and 2 steaming.

It will be seen thus that the bricks have a period of time for drying equal to that taken to burn 1½ rounds of the kiln. This is about five weeks in all, so that a brick is not drawn from the kiln till two months after it is made.

The inventor acknowledges that more fuel is consumed in the kiln than in one of ordinary form with arch, but claims that the difference is merely that required to ensure the drying of a quantity of bricks equal to the output of the kiln.

Similar arrangements for drying have been tried in England, but without much success, and it is hardly credible that the problematic saving in labour would compensate for the slowness of the output.

As a comparison, it may be mentioned that, with an efficient combination of tunnel dryer and continuous kiln, a brick may be drawn from the kiln within a fortnight from the time of making.

b. *Dryers furnished with flues in the floor, heated by waste heat from kilns, coke fires, or steam.*

This section of artificial drying is one of considerable importance, because of the widespread adoption of it in England, It is not largely used outside this country.

It does not include systems which are furnished with steam or hot-water pipes below a latticed floor, but only those with the heating flues embedded in the floor, on which bricks may be set to receive heat by conduction.

COKE-HEATING.

The simplest form of floor is that heated by coke fires, and Figs. 27 and 29 show the construction in horizontal and part transverse section, while Fig. 28 is a front view of the fire-

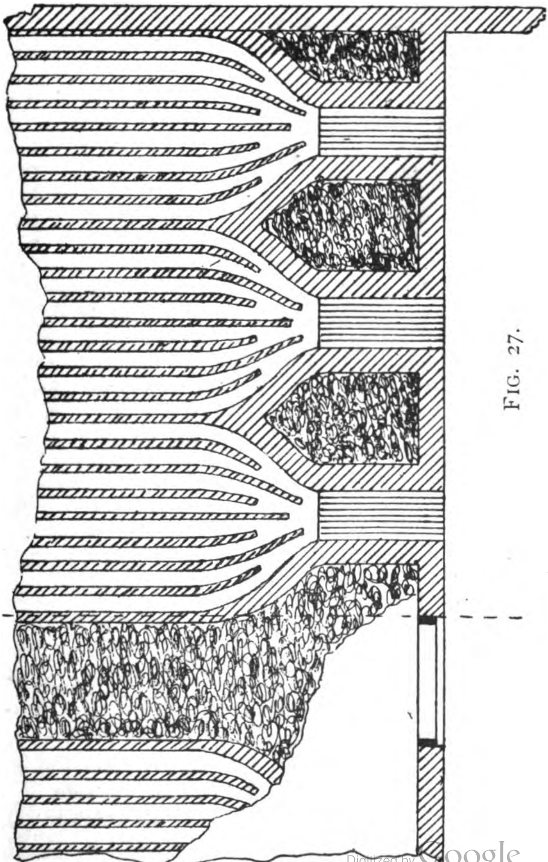


FIG. 27.

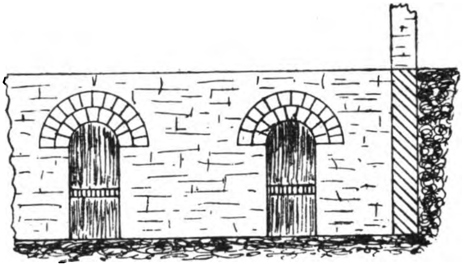


FIG. 28.

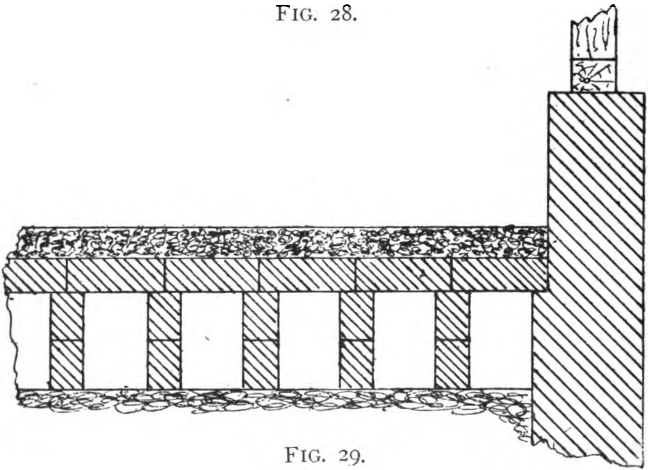


FIG. 29.

places. It is usually advisable to leave a width of about 4 feet, without flues, for a barrow path, and five grates will supply the heat to a shed 36 feet wide—three on one side and two on the other. The flues cannot be carried more than 100 feet in length, as the gases get cooled in that distance, as much as they may to admit of obtaining sufficient draught for combustion. The flues must be sloped slightly from the fires up to the chimneys, and one chimney on each side of the gangway collects the smoke from all the flues on its own side.

The flues are covered with a layer of clay which may be from

3in. to 6in. thick at the hot end, and gradually tapered off towards the cool end. On the clay is spread fine sand, on which the bricks are set continuously in rows on their edges, in a single layer. When sufficiently stiffened they may be turned up on to their ends, taking up less space and more effectually utilising the heat. When nearly dry it is a convenient practice to skintle them six or eight high, along the sides of the shed, thus rendering the floor room again available at the earliest possible moment.

This method is essentially on the conduction principle, as the bricks are in contact with the source of heat supply. The aëration is but slight, and "steam" is frequently seen rising from the bricks shewing saturation of the air just above them.

The fuel consumption is large, averaging 1 lb. for every 3 lbs. of water dried.

A floor 100ft. by 36ft. will dry about half a million in a year, working winter and summer. It must be heated strongly all the year round to give this output. The labour expended on the bricks also is considerable, as it is necessary to shift them towards the hot end in order to give them the requisite progressive drying, if they are at all liable to crack in the earlier stages. Some manufacturers increase the output of coke-heated floors by the use of high chimneys constructed to give a greater draught and so effect more rapid combustion. The greater heat of the floors, so obtained, is only suited to clays which do not crack under such strong treatment. There is one point in favour of coke-heated floors, in that the fires may be banked up at night, and require no attention except during working hours.

Intermittent Use.

The fuel-heated flued floor is sometimes used intermittently. Separate enclosed floors are filled with goods stiff enough to bear piling, or they are placed on temporary racks completely filling the whole floor space. When full the shed is closed and fire lighted in the grates. The heat is gradually raised during three or four days, and then the fires are allowed to go out. Very little ventilation is provided and then only towards the

end of the process, when the goods are all but dry. The method is very extravagant in fuel consumption, but is found successful with some of the most troublesome clays, which will not bear a breath of air movement in drying.

Heating by Kiln Gases.

The same construction may be employed for making use of the heat of the products of combustion (or smoke) of kilns, due regard being had to the provision of ample area to carry the requisite volume of gases. In using heat from intermittent kilns, the draught should be obtained by means of an induced draught fan, placed so as to *draw* the gases through the flues. They then become so far cooled that they will not damage the fan. With intermittent kilns it is of course necessary to make arrangements to have one always in full fire, so as to maintain as far as possible regularity of heat supply.

With continuous kilns the fan may be placed so as to *blow* the gases through the flues, after drawing them from the kiln. The heat is, in this case, of course practically constant, but considerably lower in intensity, and the floor would need a thinner covering of clay so as to transmit it at a sufficiently quick rate.

The question of using the heat from the gases of combustion of kilns will be dealt with fully under section **3a**, and it is not necessary to say more here than that it is of considerable importance and easy of application.

Steam Heating.

The construction of a floor for using steam as the heating agent is somewhat similar to that last described, but special disposition of the flues is necessary to obtain uniform distribution of the steam.

The sub-floor must be carefully covered with a bed of cement concrete three or four inches in thickness, to render it water-tight. Neglect of this has in many instances caused much inconvenience from softening of the ground by the water of condensation.

The floor must also slope, preferably in the same direction as the steam travels, in order to carry off the condensed water.

The steam may be distributed by means of transverse heading flues out of which the branch flues lead longitudinally. A similar transverse heading flue at the far end serves to collect the condensed water, which should be pumped or conducted back for feeding the boiler, while still hot.

Some authorities prefer to distribute the steam by means of a main central longitudinal flue with branch flues at right angles to it, right and left. This probably gives a rather more equal distribution of the steam. A method of distribution of the steam, which gives complete control of a floor divided into as many sections as may be desired, is found in the provision of overhead mains with a descending branch to each section. A valve on each branch provides for the control of the steam supply which may be thus minutely adjusted according to requirements.

The steam-heated flues may be covered with brick or with iron plates, according as the clay cannot or can be dried quickly. Iron is more expensive, and is more difficult to keep tight at the joints, but when a clay will stand drying quickly, is more economical for a given output. The flues when covered with iron may be wider than those shewn in Figs. 30 and 31, but this construction should be followed if a brick covering is adopted. A layer of cement must be laid over the paving brick to make the floor damp-proof. A brick-covered floor retains heat better at night, and, except during frosty weather, may be left without steam after working hours, when the engine is not running.

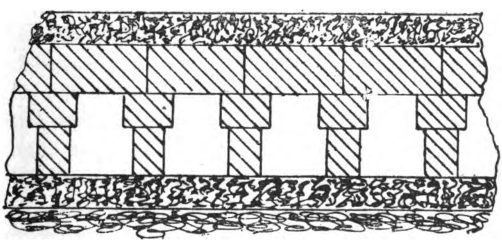


FIG. 30.

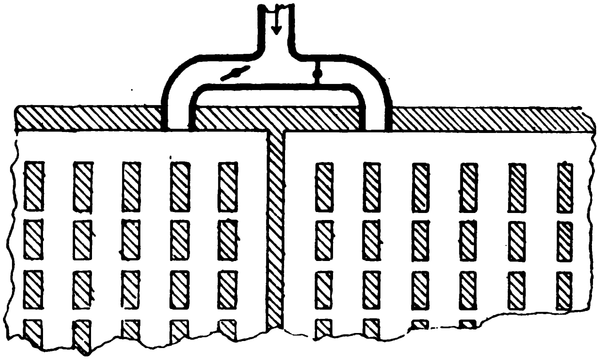


FIG. 31.

Either exhaust or live steam may be used in this form of floor. It is of course customary to use exhaust steam during the day time, when the main engine is running, and live steam from the boiler at night, when the engine is stopped. It is requisite when using live steam to admit it to the flues at a low pressure, in order to obtain a regular distribution of it in all the small flues. Exhaust steam is found to diffuse in the flues much more uniformly than live steam.

If iron plates are used for flue covering, it is usually essential to have all or a portion of the flues controlled by valves as shown in Fig. 31, so that steam may be admitted gradually during the progress of drying. On the whole the brick covering is perhaps preferable because the heat is more modified. A larger area of floor is requisite, for the same output, but the same quantity of steam will serve the larger floor. With tender clays there is a saving in labour as the heat will not be sufficient to be harmful to the newly made bricks. In this construction it is usual to have small openings as shewn in Fig. 31, at intervals throughout the lower brick on edge of the division walls between the flues, so that each one is in communication with those on each side at many points.

Steam heated floors are usually covered throughout with goods to be dried. First, a single layer is placed on them till

the bricks become stiff enough to be handled and placed upon one another, four or five high. Newly made bricks may then be piled up to eight or more high, on these, and they are not touched again till all are dry. Some makers place the bricks in a single layer only, on end, turning them upside down when the lower part is dry.

A steam floor is not usually constructed so long as a coke heated one, but may be conveniently wider. The floor, however, may be of any desired dimensions if the method of distribution of steam above described is adopted, wherein service pipes are taken off at intervals from a main supply.

A floor covered with iron 60ft. by 50ft. in full work will give about 30,000 dry bricks per week. The exhaust steam from an engine giving fifty indicated horse-power would supply two such floors, and if the bricks contained each 1 lb. of water of manufacture, an additional 15 cwt. of coal would have to be burned in the boiler at night to supply the live steam necessary to effect the drying of this quantity of 12,000 per day.

Since a power of fifty-horse indicated would suffice to make quite 120,000 bricks per week, it will be seen that the exhaust steam will not dry more than one quarter of the output on this system, even if the bricks contain so little as 1 lb. of water of manufacture.

This can be verified simply as follows :—

The engine will require say 20 lbs. of steam per horse-power per hour, or 10,000 lbs. per day of ten hours.

An efficient steam dryer takes 1½ lbs. of exhaust steam to dry 1 lb. of water out of a brick, therefore 10,000 lbs. of exhaust steam would dry 6,600 bricks under favourable conditions, or say, 5,000 on a steam floor.

Several patents have been taken out for steam drying floors constructed in vitrified or glazed ware made of a rectangular section and tubular. These do not need a thick cement bed and covering, as they are impervious to moisture and strong enough to support the traffic of loaded barrows. Being thinner than brick flues they transmit heat readily.

SABINE'S FLOOR.

A practical success in this direction is obtained by Sabine's Patent Steam Quarries, made by Sutton & Co., of Overseal,

near Ashby-de-la-Zouch. The heading flue for steam supply is made up of a length of these quarries, 12in. by 9in. with a single tube. Each quarry is 4in. in total thickness and perforated on one edge with two holes, which serve to distribute the steam into the longitudinal flues. The longitudinal flues are formed by quarries 18in. by 12in. with two tubes in each.

Each tube corresponds with a hole in the header quarry. The outlet quarry is of the same form and continuous with the longitudinal quarry, but the tubes are stopped at one end and provided each with a hole on the under side to let out the condensation water. Below the outlet holes are placed channel quarries with the channel transverse to the flues, and these form a continuous channel to carry away the water. The quarries are made in salt-glazed stoneware, and are bedded and jointed in cement. Only a thin layer of cement is required, and the resulting floor is very easy of construction and perfect.

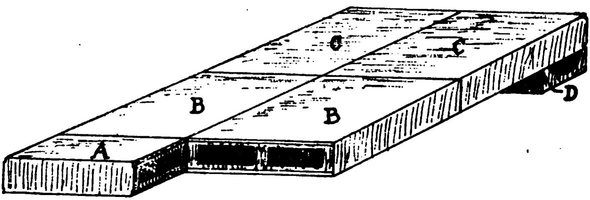


FIG. 32.

This is illustrated in Fig. 32, in which A is the header, B the main, C the outlet, D the channel quarry. This floor admits of being laid in sections, each with valve for control, and its own row of feeder quarries.

COST OF STEAM FLOORS.

The cost of construction of steam floors may be put roughly as follows, exclusive of the necessary excavation and valves for control :—

1.—Cast-iron covered flues with cement concrete bed and brick flue-forming partitions, 20/- per square yard.

2 —Brick covered flues with concrete bed and covering, 10/- per square yard.

3.—Sabine's Patent Quarries, 8/- per square yard.

The iron covered steam floor is not expensive in proportion to its output, but so few clays will admit of rapid drying by contact with the source of heat, that it is not to be recommended. Sabine's floor seems to fulfil nearly, if not quite all, the requirements of this method of drying and is worthy of careful notice.

The principle of using exhaust steam for drying is undoubtedly one of the best, but the floor method is not the most economical way of employing it. It is the principal way in which the "conduction" method of supplying heat to the goods to be dried is made use of, a method which is not to be recommended except for common goods, which do not crack or warp easily under such strong treatment. The aëration also is unsatisfactory, and because of its feebleness, much heat is lost by radiation.

The erection of racks as shewn in Fig. 18 on the iron covered steam floor, should give more economical and more satisfactory results than the method of setting in hack form. The radiation method of heating them comes into play with less risk of damage to delicate goods. When racks are employed, however, it is more usual to use pipes for heating, rather than flues in the floor.

c *Dryers furnished with flues or pipes detached from the floor, heated by coke, hot water, or steam.*

A primitive form of dryer comes under this heading. A furnace is constructed in brick at one end of and within a shed. The flue for the products of combustion of coal or coke is in the form of a long cast-iron stove pipe of 6in. diameter, which traverses the whole length of the shed, sloping gradually upwards towards the distant end, and discharging the smoke into the outer air. Radiation effects the drying for the most part, but a latticed floor may be placed above one or more such pipes, thus utilising also the ascending currents of warmed air.

Sets of iron flues may be similarly placed in channels in the floor of a shed, and latticed over, air from outside being admitted to the passage on each side of the pipe.

It is needless to remark that these are not economical systems, and are not to be recommended

Hot-Water Heating.

Hot-water and steam are employed largely in dryers included under this head, making use for the most part of the radiation principle of heating. Generally speaking, the drying is gradual, and in consequence of the method of heat supply, the aëration required is but slight, the air being a moisture-carrying medium and not an evaporating medium. Hence it is a method particularly suited for drying high-class clays, and those which may neither be heated strongly or subjected to currents of air, The goods are dried evenly and not appreciably more on the surface than inside, unless very large and thick.

The ordinary hot-water heating system is largely used in the potteries. The buildings in which the moulding and trimming are done are all provided with the ordinary 4in. cast-iron hot-water pipes, which are so familiar to everyone that they need not be described.

The goods are set about the rooms on the floors and benches, or on shelves, and are in continual and gradual progress of drying from the time they are moulded till ready for the biscuiting-kiln.

More elaborate methods of drying to be described later, are sometimes employed, but it is doubtful whether any more simple, convenient, or efficient mode is possible in view of the repeated handling necessary in the production of all classes of china and earthenware. The stone-ware pottery trade which deals with larger and thicker masses of material employs other methods, more suited to its particular requirements.

Large stoneware pipes, tiles or chimney pots may be successfully dried in sheds heated by a system of hot water or steam pipes. The sheds may be constructed with one or more upper floors, which are latticed and provided with a series of heating pipes beneath them. The heat from the pipes radiates both downwards and upwards, and the warm air also effects drying in ascending through the latticed floor, and amongst the goods placed on it. The ground floor may be provided with pipes at a low-level round the sides of the shed. The ordinary hot-water pipe does not conveniently serve in such an arrangement. It is better to employ live steam or "Perkins's" hot-water system.

Perkins's Hot-Water System.

This latter system is not much in use, but is particularly convenient and efficient. It is composed entirely of hydraulic pipe of $\frac{7}{8}$in. bore constructed to sustain a pressure of 3,000 lbs. to the square inch.

The whole circuit is composed of this pipe, the heating apparatus being in the form of a close coil of the pipe itself. The only adjuncts are a furnace built round the coil, and an expansion pipe, of 3in. bore, which provides for the expansion of the water when heated. Several great advantages attend the use of this system :—

1. The pipe is small.
2. The system does not require constant refilling with water.
3. The utmost heat is obtained from the fuel.
4. The temperature of the pipes is high and nearly uniform throughout.
5. The pipes may be carried in any direction.

The system is closed and when once in full working order with sound joints, does not require the addition of water more than once a month, and then but a very small quantity. The water is under such great pressure that it obtains temperatures considerably over 300° F., and it circulates so rapidly that on returning to the coil it has not, as a rule, fallen below 200°. A thousand feet run of the pipe may be maintained at these temperatures with a well constructed furnace, with an expenditure of 2 cwt. of coke per day. Such a length of pipe with its coil, furnace and fittings costs about £45 and will maintain a shed of 30,000 cubic feet capacity at an average temperature of 70° F. in winter.

Given a good rise of some 5 or 6 feet at starting from the furnace, the pipe may afterwards be carried up and down in any desired direction without appreciably affecting the rapidity of the circulation. Horizontal zig-zags may be placed under the latticed floors of a two or three-storey shed.

The system is in the form of a continuous pipe and cannot be branched in any way. The lengths of pipe are screwed at the

ends with right and left hand threads and the sockets are similarly screwed. The end of one pipe has a chisel edge which butts against a flat end on the next pipe, so that when the socket is screwed up it draws the two ends together firmly, making a contact joint without any kind of packing. Bends are not used, the pipe itself being bent to any desired angle and sweep.

An interesting application of the system is found in the drying of wheel-made chimney pots, and Figs. 33 and 34 on pp. 67 and 68 shew a shed applied to this purpose.

Pots more than 1ft. 6ins. high are not finished at one operation; the solid column of clay is turned first at one end to form the bottom half of the pot, and this turned portion must be partially dried to stiffen it ready for the turning of the upper half. To obtain this stiffening an overhead heat is required, and is very effectually provided by horizontal rows of hot-water piping placed about 5ft. above ground. A section of such an arrangement is given in Fig. 33, in which a shed is shewn with a latticed floor 7ft. above ground on which the finished pots are placed to complete the drying. Fig. 34 shews a sectional plan of the shed at a height of 6ft. from the ground, the black line D indicating the piping, the potter's wheel is at A, the heap of prepared clay at B, the furnace at C, and the drying chimney pots at E.

The fire may be banked at night so as to keep alight till morning, and it is not therefore necessary to provide night attendance, as it is with steam heating. This method of heating is not so suitable for drying large quantities of bricks, which must be turned out rapidly in bulk. It will not yield sufficient heat, unless installed in considerable quantity, but for delicate ware, and large lumps which must be dried slowly, it is very convenient and economical, in addition to being suitable for pipe and tile drying.

STEAM.

The medium par excellence for transmitting heat to drying sheds is steam, and the reasons of its special suitability are to be found in its high latent heat and moderate temperature. This latent heat is the heat absorbed in the process of evaporation

from water, heat which is given out again on its being condensed back again into water.

One pound of steam in condensing into water yields ten times as much heat as one pound of water yields in cooling from 200°

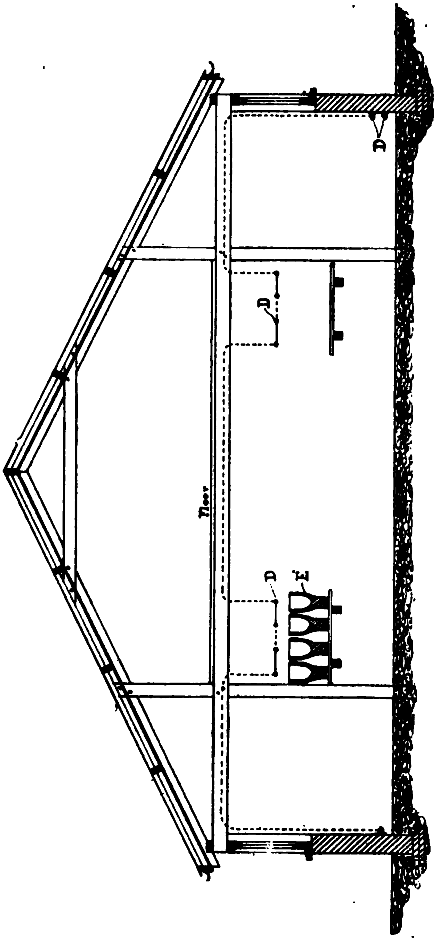


FIG. 33.

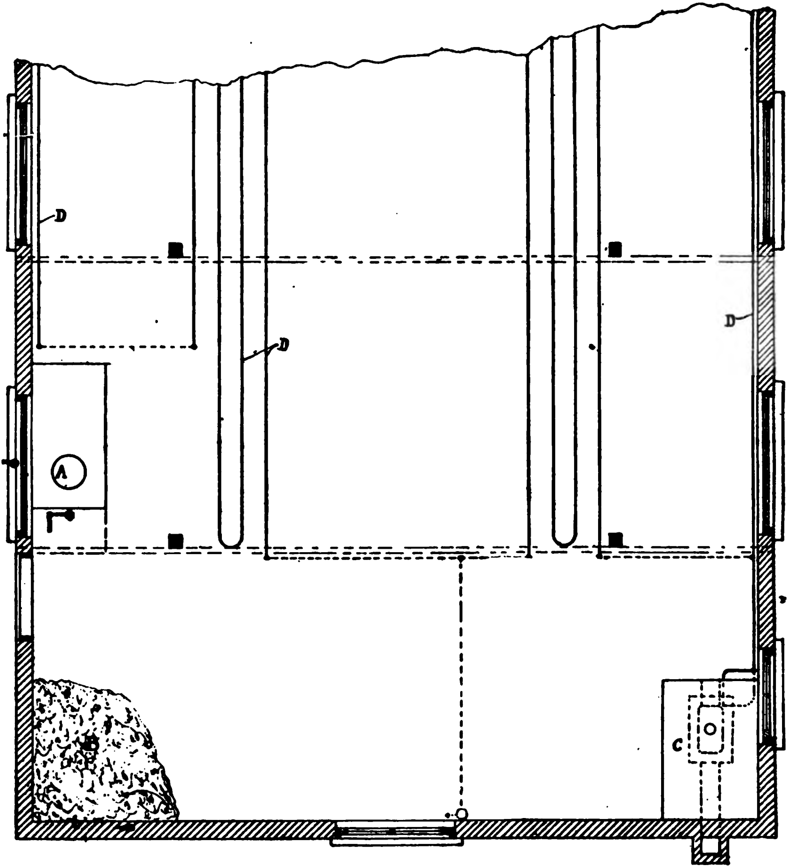


FIG. 34.

to 100° and about forty times as much as one pound of air in cooling through the same range. Hence as a medium for introducing heat into a dryer it is far less bulky than air or water.

Exhaust steam from the engine on a brickworks is an inevitable waste product and should invariably be made use of; and

for the additional reason that the condensed water can be returned hot to the boiler, and is free from impurities. Its place can, if required, be taken by live steam when the machinery is not working.

Live steam may be used in a system of pipes similar in arrangement to that described in connection with Perkins's hot water system, pipes of 1-in. diameter being employed. Arrangements must, of course, be provided for the draining away of the condensed water, and for this reason a main header pipe of larger diameter with many branches is more convenient than a continuous circuit. The piping cannot so well be carried up and down as those of the hot-water system.

The most convenient method of application of exhaust steam, however, is by means of pipes of about 3in. diameter laid in trenches below the floor level.

Steam Pipes in a Shed provided with Racks.

This method may be used in a shed provided with racks as shewn in Fig. 18, a pipe being laid under each stage, or in the gangways or both. Or, again, the pipes may be laid longitudinally, traversing the racks and gangways, 3ft. apart with a header pipe of larger diameter at the end nearest the source of supply. With such an arrangement bricks may be dried in 10 or 12 days, and those first dry may be at once removed to the kiln, making room for a fresh supply of newly-made bricks. All the accommodation of the shed is utilised in a continuous manner, and access to the goods during the drying process for re-pressing or trimming is always possible.

Many forms of dryers are in use, employing exhaust or live steam or both, distributed in pipes and provided with simple aëration. It is perhaps the most important and most efficient of the artifical drying systems, acting as it does by radiated heat and feeble aëration, and it may be safely adopted for the most tender clays. The arrangement mentioned above is probably very efficient, because continuous, but the majority of forms are intermittent in action, the goods being stacked in them in bulk and left till all are dry. In this way heat is lost when the contents of the dryer are approaching the end of the

drying process, and, unless valves are inserted for shutting off the steam, also during the process of emptying.

Steam Pipes in Floor Trenches.

A simple dryer in shed form is that in which 3in. or 4in. pipes are laid in trenches with brick partitions, 3ft. 6in. apart. Nine inch partitions are constructed, and on the walls so formed, cradle pallets 3ft. long are supported transverse to the pipes, and carrying nine bricks each on edge. Fig. 35 shews a cross section of a portion of such an arrangement.

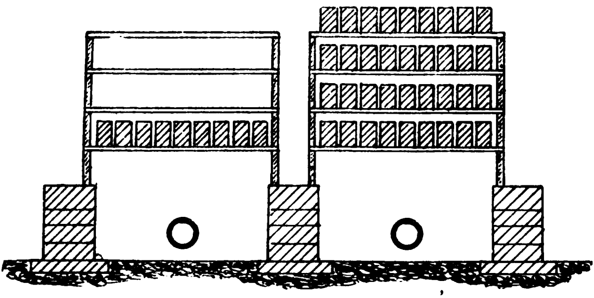


Fig. 35

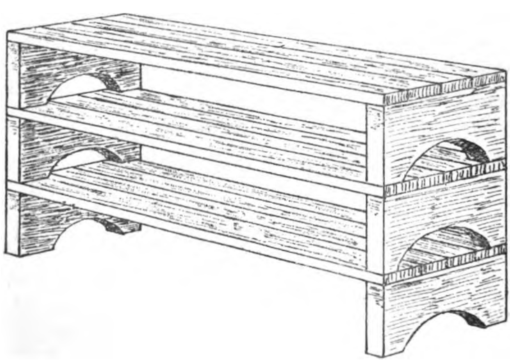


Fig. 36.

The pallets have a foot at each end, as illustrated in Fig. 36, and may be placed on the top of one another 8 or 9 high. They cost about 8d. each. The whole floor may be thus filled and as those first stacked become dry, they may be removed to the kiln and replaced by newly made bricks.

Soft bricks can be dried thus in quantity, as they have only to bear their own weight.

HOOPER & CO.'S FLOOR.

An improved form of this system is the subject of a patent taken out by Messrs. Ashby & Batley, in 1896. It is particularly efficient and suitable for bricks stiff enough to bear stacking six high, when newly made. It is illustrated in Fig. 37, which shews a portion of the floor of one chamber in isometric projection.

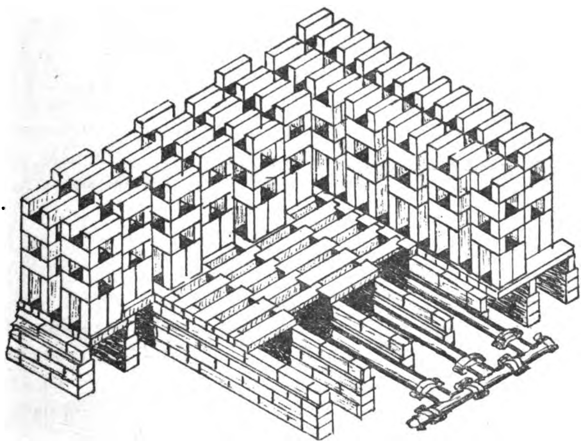


FIG. 37.

The steam pipes traverse a series of small chambers separated by partitions about 8ft. high. All the chambers are enclosed under one roof, and the vapour rising from the goods is carried off by simple ventilation at the gable ends of the shed.

The special features of the invention are the checkered block paving, and the method of setting the bricks for drying.

The pipes, 3in. in diameter, are only 12in. apart with 4½in brick partitions, across which the wood blocks are laid as shewn in the illustration.

The division of the dryer into chambers divided off from one another is a useful arrangement when drying difficult clay.

A chamber can be quickly filled with wet bricks and then shut, so that no currents of air arise which would cause the bricks to crack. The drying is largely by radiation and the aëration may be reduced to a minimum.

On this floor bricks made stiff plastic will dry in six days, without cracking, using exhaust steam by day, and live steam at night.

This floor costs about 12/- per square yard, and a floor to dry one million in a year should have an area of about 225 square yards.

Keller's Dryer.

Under the present head (1c of the sub-division) comes, perhaps, a dryer which has obtained a reputation in Germany in a very short time. It is the invention of E. Keller, of Laggenbeck, in Westphalia, and is constructed in the form of tunnels some 80 feet long, separated from one another by wooden or brick partitions.

The tunnels are roofed with a thick thatch of straw on one side, with very steep slope, and on the opposite side ordinary double wood roofing only is fixed, rendered waterproof by asphalt. The outer boarding laps over the straw at the ridge line, but does not meet it by about one inch. The lower ends of the straw are also cut a little short of the next roof to allow the condensed water to drip free of it. On the under side of the thatch, as at *c*, some of the straws are cut short so that the free ends are exposed within the tunnel. Each tunnel has its roof in this form as shewn in Fig. 38, and the special virtue is claimed for the straw of allowing the moisture to diffuse into the outer air through the slit *d* at the ridge and between the straws while preventing the entrance of cold air from without.

The heat is supplied by two steam pipes laid near the ground on each side along the entire length of the tunnel. A track of

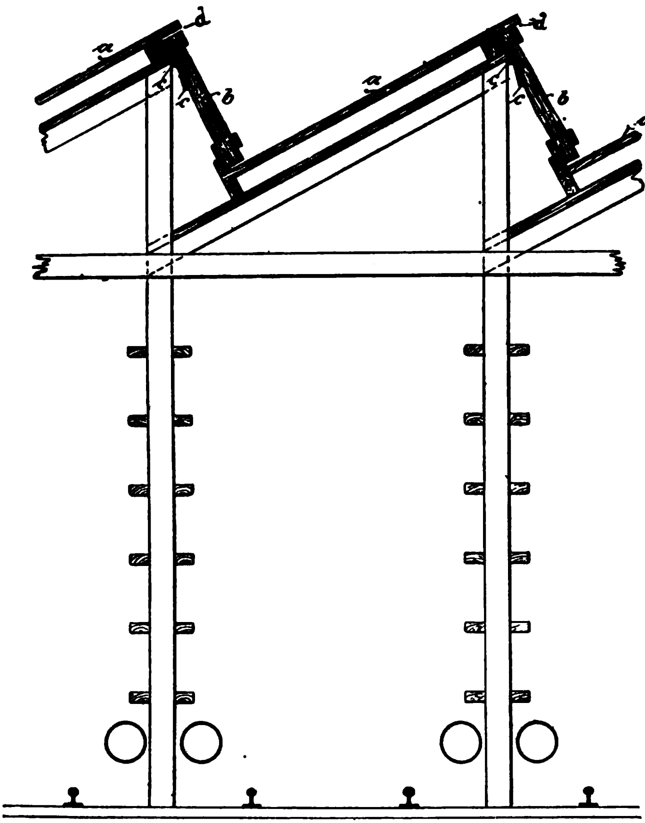


FIG. 38.

light rails is laid in each, along which the bricks to be dried are wheeled on a special and ingenious barrow which carries the bricks on pallets. The walls of the tunnel are provided with spaced projecting ledges in wood or brick, on to which the pallets are deposited, and when the tunnel is filled it is closed till the bricks in it are all dry.

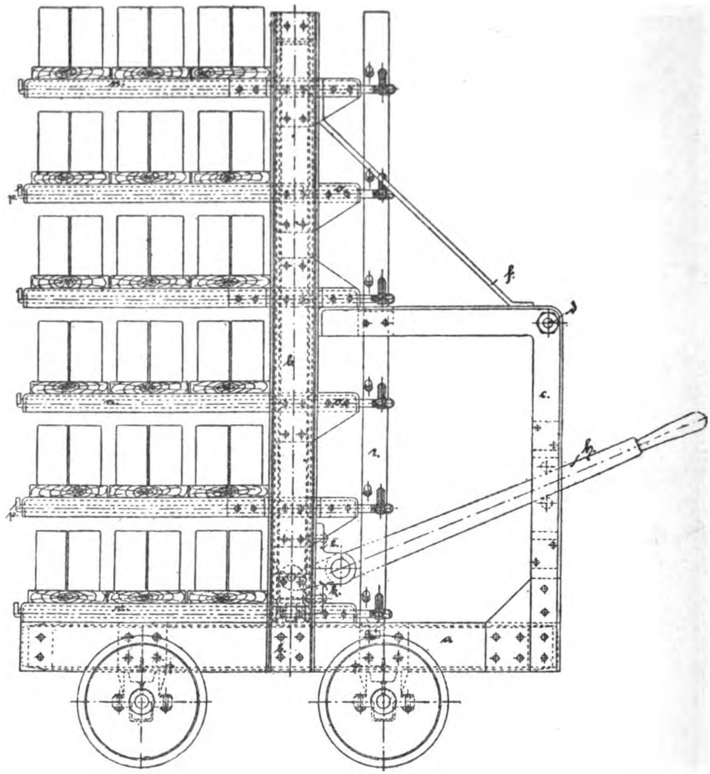


FIG. 39.

The barrow shewn in Fig. 39 is constructed to carry 96 or 108 bricks on pallet boards. The projecting arms are arranged so that they can be raised or lowered by means of the lever, and the method of using it is as follows :—

Adjacent to the machine or moulding tables is a wood rack with ledges exactly corresponding in height and spacing with those in the tunnels, Fig. 40. Its capacity is the same as the barrow, viz., 12 pallets holding eight bricks each

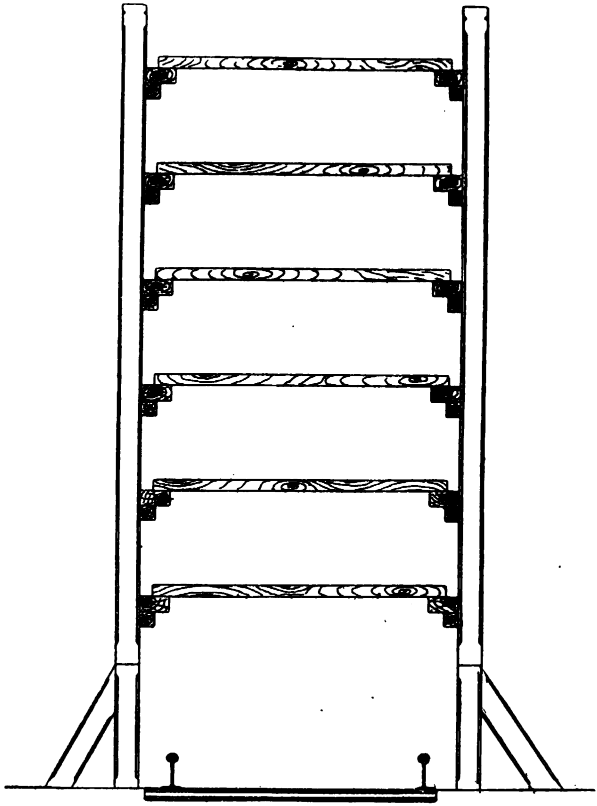


FIG. 40.

or 18 pallets holding six bricks each, and it is filled with newly-made bricks. The empty barrow with the projecting arms lowered is now run on the rails up to this rack until the arms pass under the pallets into the requisite position. The lever *h* is pressed down raising the barrow arms and lifting all the pallets simultaneously off their ledges. The loaded barrow is now run to the tunnel and pushed inside it up to the last deposited pallets. The lever is raised, lowering the loaded

pallets on to the ledges on the tunnel walls, where they remain till the drying operation is completed.

The unloading of the tunnels is done from the further extremity by means of a similar barrow which takes the dry bricks direct to the kiln, so avoiding all handling after manufacture until set for burning.

These tunnels are intermittent in action, but, nevertheless, have proved very economical and efficient. About 14 of them are required for a daily output of 10,000 bricks, the time of drying being from 3 to 4½ days. The exhaust steam from an engine of about 30 i.h.p. being used, the live steam for night work is found to be given by a coal consumption of about 2 cwt. per 1,000. Such an installation costs in Germany about £800. It requires only three of the special barrows, and two men are sufficient to load the wet bricks into the tunnels.

It is instructive to observe how carefully statistics are compiled and published in Germany on the working of brickmaking appliances. The clayworker may rely on obtaining correct information as to the cost of installation and working.

The subjoined table from the *Deutscher Töpfer und Ziegler-Zeitung* as to practical tests of the Keller dryer are interesting and useful, and it would be to the advantage of the trade in England to have access to correspondingly reliable information from actual practice.

Herr Keller's contention that the straw covering has a specific value is, perhaps, hardly borne out, for in practice a great deal of condensation occurs in the earlier stages of drying on the walls and roof of the tunnel, and the users have in some instances been compelled to provide accessory openings in the roof for the purpose of getting rid of the excess of moisture. The aëration is undoubtedly too slight and though the use of straw with its fine tubes is ingenious, there is no evident objection to a means of ventilation more under control and at the same time more efficient. The striking feature of the invention is the use of the special barrow, which reduces the handling to a minimum, while it does away with the necessity for a large number of steel cars.

TABLE VII.

Proprietors of Works.	Situation.	Tunnels.	Cars.	Output in 24 hours.	Description of Goods.	Nature of Clay.	Water of Manufacture per brick.	Horse-power of Engine.	Time of drying.	Cost of Coal for drying per 1000.
							lbs.		Days.	
Aulenbrock and Schürbrock	Laer b/Iburg	13	3	9,000	Common and facing bricks	Clay	1·5	30	3½ to 4	1/4
Agst & Son	Auerbach	14	3	12,000	Facings	Delicate loam	2·2	30	3	1/9
H. Pieper	Wernigerode	14	3	8,000	Common and facing bricks	Red clay...	1·37	30	3	2/0
W. Schulze-Velmede	Camen	15	3	12,000	Common bricks	Loam	1·5	35	2½	Exhaust steam only
Steam Brick Works	Ueckingen ...	17	4	12,000	Ditto	Delicate loam	1·75	55	4½	1/7
H. Kretschmann	Borsdorf	14	3	10,000	Facings	Yellow-burning clay	1·8	120	4½	1/5

In consequence of this the installation cost for a given output compares favourably with other systems, and the most tender clays can be successfully dried with economy.

With reference to the inclusion of this dryer under the present subdivision, it may be remarked that though "special" means of ventilation are employed, these means do not really ventilate in the sense in which the word is used in these papers. They only effect aëration and that in a very slight degree, whereas ventilation implies the movement of a considerable body of air.

CHAPTER V.

II.—Dryers Warmed and Ventilated with the Goods Stationary.

This subdivision includes both shed and tunnel form dryers, the former being used in a continuous manner, heated to a moderate temperature not injurious to workmen, and therefore always accessible. The latter are used intermittently like the last described dryer, and are closed during the drying process.

a.—*Dryers placed over or against kilns utilising the waste heat of radiation and burned brick cooling, provided with special means of controlling the air currents.*

Under this heading comes a large number of dryers in use in Germany. They are elaborate and expensive structures, but little favoured in England where labour is more than double in cost. Nevertheless they must be described here because of the great importance of them on the Continent.

An examination of the heat distribution in a continuous kiln of the Hoffmann type is necessary to give an indication of the efficiency of this form of dryer. This, however, is not easily determined, the problem being very elusive for various reasons which cannot be entered into here. It must suffice to remark that authorities are of opinion that the chemical change effected by burning a brick does not absorb an appreciable amount of

heat unless chalk is present in large proportion, or other ingredients which are chemically dissociated. Heat is absorbed in driving off water, but all the remainder of that produced by the consumption of the coal is lost by way of the smoke, the radiation from kiln walls, and the cooling after a certain temperature is reached of the burned bricks and the kiln interior.

A very careful and extended examination of the processes involved has led to the following as an approximate disposition of the heat in a Hoffmann kiln burning common bricks at a temperature of 1800° to 1900° F. The bricks are taken to weigh 8½-lbs. when made, 7-lbs. before and 6½-lbs. after burning, the differences being water driven off. The coal consumption of the kiln is taken at 3½ per cent. of the burnt weight of the bricks.

HEAT DISTRIBUTION.

1. Evaporation of water	18½ per cent.
2. Dissipated by chimney	30 „
3. Radiation from exterior ... } 4. Cooling of internal kiln walls }	44 „
5. Cooling of burned bricks (from 200° to 50° F.)	7½ „
	100

Of these the last three items are available for drying in the German form of dryer.

Taking, now, an output of 100,000 per week, the coal required for burning may be put at 10¼ tons; of this 5¼ tons (51½ per cent.) is realised in the form of dryer in question, as available for the drying of newly-made bricks.

Taking the efficiency of the dryer at 4 cwt. per 1,000, it will be seen that its output would be 26,500 per week, or 26½ per cent. of the output of the kiln. This entails supplementary drying apparatus for the balance of 73,500, and considering the great cost of installation and of labour in usage, it will be seen that the method is not to be recommended in this country for common brick drying.

This calculation of course deals with the heat yielded for drying purposes by the kiln, and does not take into consideration

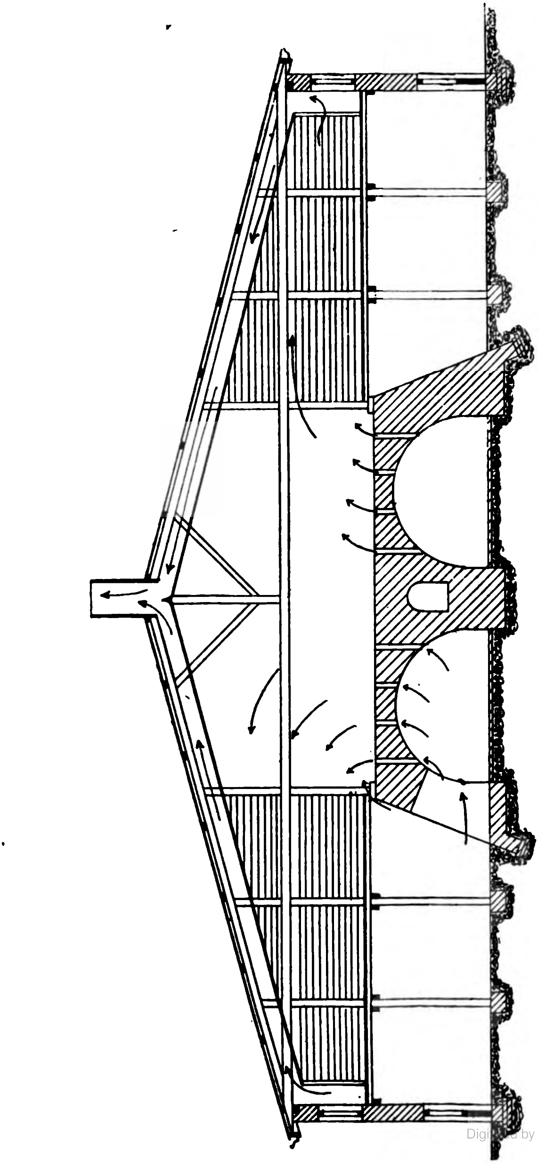


FIG. 41.

the fact that in summer the air has inherent drying capacity. It follows from this that a larger quantity than indicated by the calculation would be dried in summer, but the supplementary number would equally well be dried in a shed at the ground level; such as is shewn in Fig. 18, and much labour would be saved.

In summer these dryers in actual practice dry rather more than half the quantity the kiln burns. In winter their production is small, and their use unadvisable during frosty weather.

For the drying of firebricks or other goods burned in continuous kilns at a higher temperature this type of dryer is more serviceable. The coal consumption for a burning temperature of upwards of 2,400°F. is as much as 8 per cent. of the burnt weight of the goods, and there is consequently a much greater quantity of waste heat available which may with advantage be made use of.

In this case the waste heat of radiation and cooling amounts to upwards of 65% of the total, and with a similar output to that last described, would suffice to dry perhaps 80% of the bricks burned in the kiln.

German authorities, while strongly recommending the adoption of the system, acknowledge that there is great practical difficulty in equalising and controlling the heat distribution. This will be understood, and the ingenious attempts to overcome the objection appreciated on reference to the descriptions of these dryers which follow.

OHLE.

Fig. 41 shews a section of a dryer of the type invented by Ohle, though not drawn exactly to his detail.

It will be observed that it differs from the dryer shewn in Fig. 24, in that it is provided with special means of directing the currents of warm air. The racks are not placed over the kiln itself, but are disposed on each side of it. A close floor is provided under them with a narrow space between it and the kiln walls. A close ceiling is also constructed with a narrow space next the eaves of the roof. The warmed air is therefore compelled to pass through the uncovered feed-holes of kiln chambers in process of cooling,

and also over the outer kiln wall faces, and it rises into the space above the kiln. It then moves laterally through the brick racks on each side and passes at the eaves into the space between the ceiling and roofing, carrying with it the moisture dried out of the bricks.

Chimneys at intervals along the ridge serve to carry off and give the required ascensional force to the air, which, as previously stated, must always leave the dryer at a temperature some 8° or 10° higher than that of the outer air.

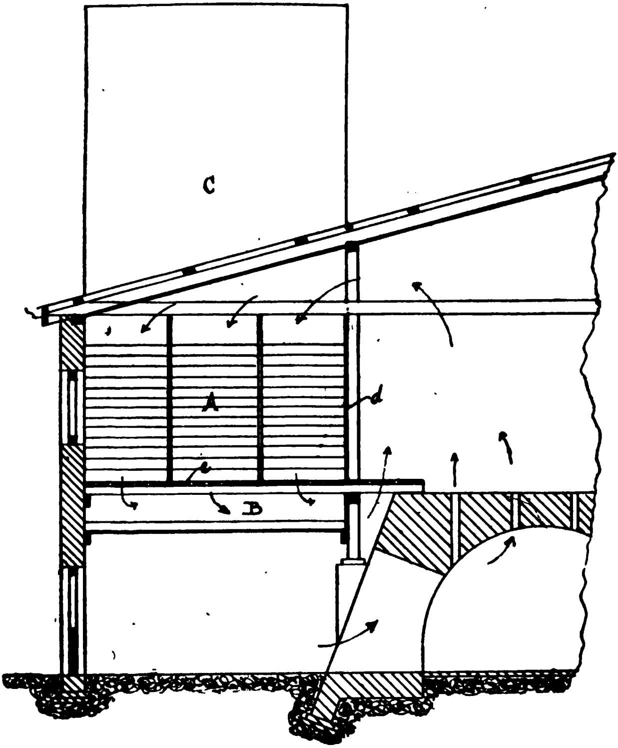


FIG. 42.

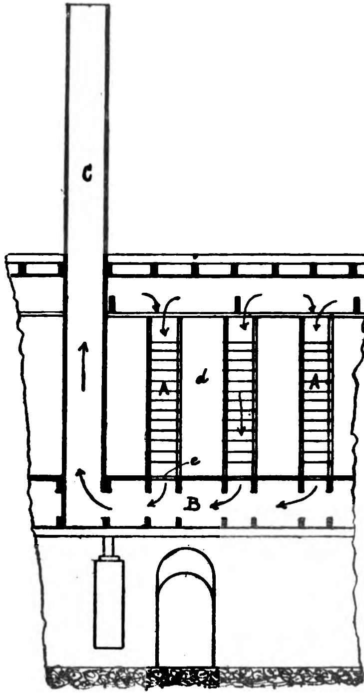


FIG. 43.

COHRS.

Ohle's system was introduced in 1886, and a somewhat earlier method of ventilating this type of dryer is shown in Figs. 42 and 43, the former being a transverse and the latter a longitudinal section.

This is the invention of Cohrs, patented in 1883, and in it the air warmed by the kiln is transmitted through the racks A in a downward direction.

In order to compel it to take this path a partition *d* is constructed along the ends of the racks nearest the kiln. Doors in this partition give access to the gangways between the racks.

After traversing the racks and performing so much of the drying operation in its passage as it is capable of, the air enters a chamber B under the floor, by way of the openings *e*.

This chamber is in communication with the chimney C, constructed in wood.

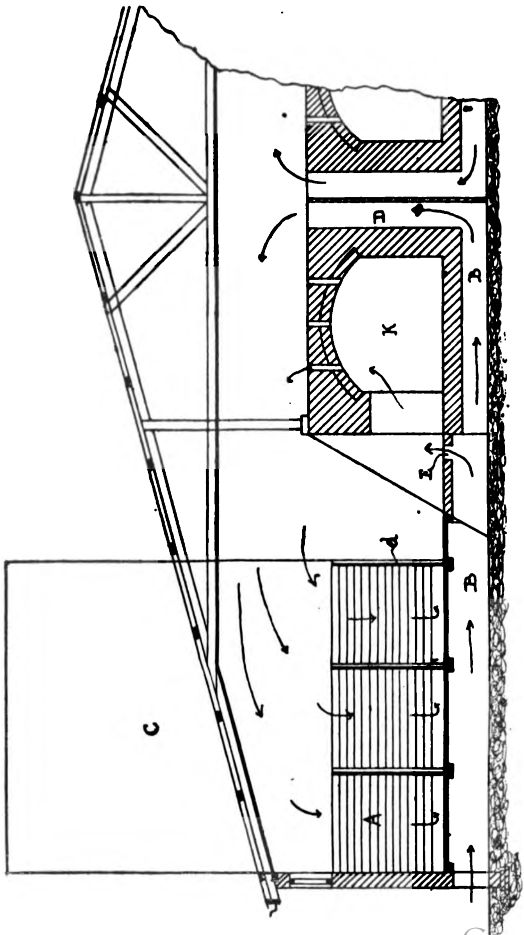


FIG. 44.

The divisions of the dryer served by one chimney are 15 to 20 feet in length, and there is consequently a row of these chimneys along each side of the kiln. Each chimney is in width about one-sixth of its length, such length being the same as that of the racks.

The arrows in the figures indicate the direction of the air currents.

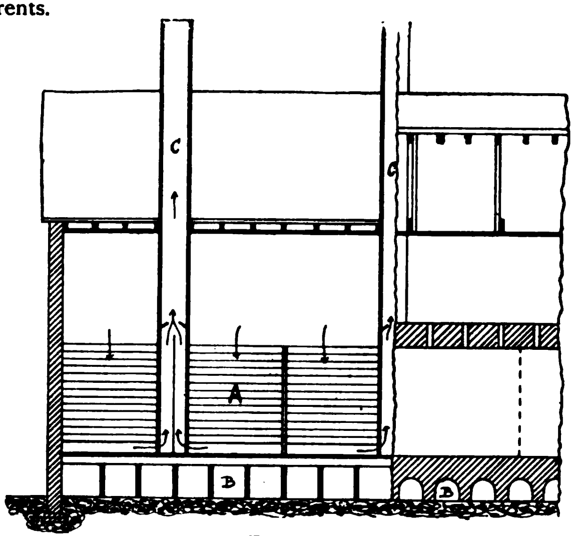


FIG. 45.

HOLZMANN

. Figs. 44, 45 and 46 show one of the most elaborate of these systems. It was introduced by Holzmann in 1891, and has the advantage of racks at ground level instead of on a level with the top of the kiln.

In the illustrations Fig. 44 is a partial cross section, Fig. 45 a partial longitudinal section, Fig. 46 a partial plan at floor level. The section Fig. 45 is taken on the line MN of Fig. 46. The peculiar feature is the honeycombing of the kiln walls, external and internal. The kiln chambers are seen at K. Below them and transverse to them is a series of channels B communicating with the open air.

Air enters under the floor of the dryer through the channels B. Portions of it passing through the openings E are warmed by the outer kiln walls. The remainder passing under the kiln chamber floors and rising through the channels D into the

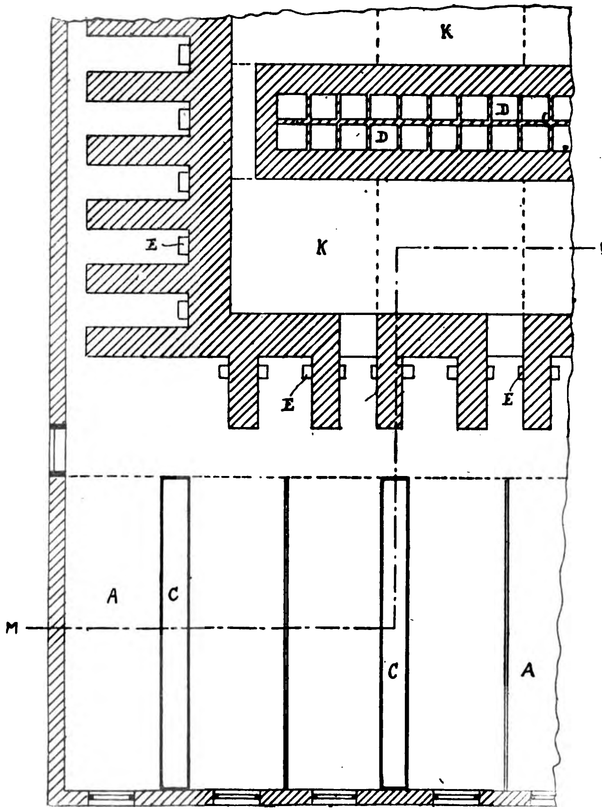


FIG. 46.

space above the kiln, is warmed by contact with the middle walls of the kiln.

The whole of the air is then directed, as in the system of Cohrs, downward through the racks, and at the base of them is

drawn into the chimneys C. The chimneys are provided with baffles to prevent downdraught due to wind.

Special means, not shown in the figures, are constructed to direct the air currents into the desired sections of the racks or to close them.

It is evident that the dryer is a most costly one to construct considering the uncertainty and insufficiency of the output.

Hotop.

The invention of Hotop, introduced in 1893, is characterised by the adoption of a ventilating fan, and it also admits of supplementary heating apparatus to augment the output.

A series of transverse racks A (Figs. 47 and 48), is enclosed by walls at each end and along the exterior. The sides next the kiln are provided with wooden partitions and doors giving access to the gangways between the racks. A ceiling *f* over the racks is provided with apertures *h* over each gangway, through which the air warmed by the waste heat of the kiln is drawn from the collecting chamber B.

Similarly the floor *e* has openings *g* through which the air passes after doing its work into two chambers C below ground

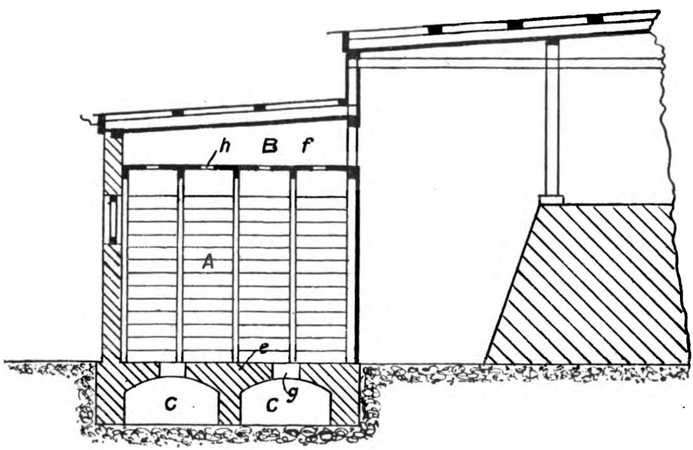


Fig. 47.

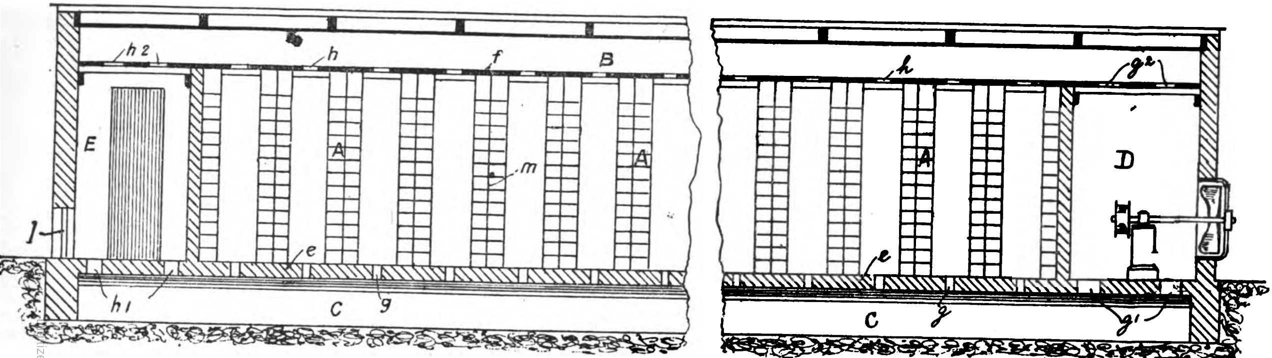


FIG. 48.

level. The openings *g* and *h* are provided with valves so that they may be opened and closed at will.

At D is the fan chamber and at E a chamber for supplementary heating apparatus. These are also provided with controllable openings in the floor and ceiling, *g*1, *g*2, and *h*1, *h*2 respectively.

Shutters are provided for closing the chamber B if it is desired to use only the heating apparatus in E.

When using the air warmed by the kiln it is drawn from above downward through the racks into the collecting chambers C, thence it passes by the openings *g*1 into the fan chamber and through the fan. If the heating apparatus in the chamber E is used, the air entering from outside through the door *l* passes through the openings *h*2 into the chamber B (*h*1 being closed), and thence as before. The direction of the current may be reversed by closing *g*1 and *h*2 and opening *g*2 and *h*1. The use of means for regulating the openings in the ceiling and floor of each gangway, provides for a graduation of the drying process. When first filled with wet goods the openings are partially uncovered only so as to admit but little air. As the drying progresses more and more air may be admitted.

In some cases the racks have complete partitions in the middle of them as at *m*, thus completely isolating each gangway so that it may be worked independently.

The system of Hotop is evidently the most practicable of hose which are included under this heading. In comparison with others it is much less costly to construct, the racks are at ground-level and the addition of mechanical ventilation and means of regulating the air admission, and a supplementary means of heating, render it capable of complete control and a satisfactory output.

MENSING.

An earlier form of dryer coming under this section and calling for passing notice is that of Mensing introduced about the year 1859.

It takes the form of separate chambers, which are filled and dried intermittently, and are in communication by means of

flues in the ground with a series of intermittent down-draught kilns. The heat for drying may be in the form of air, warmed by bricks cooling after being burned, or the gases of combustion during burning may be partly drawn through the chambers. In the former case the drying takes five to six days, the chambers being constructed to hold 2,000 bricks each.

The hot air is admitted to each chamber by an opening in the floor at one end and withdrawn by a similar opening at the other end in connection with a chimney.

The use of the gases of combustion in this system was introduced by Bührer and Hamel in 1869.

2*b*. *Dryers furnished with heating flues and ventilating chimneys.*

This sub-division comprises any form of shed to which access is usual to remove and replace dry goods, in which the heat is supplied by fuel or steam-heated flues, and a special chimney is provided in order to create a considerable movement of air.

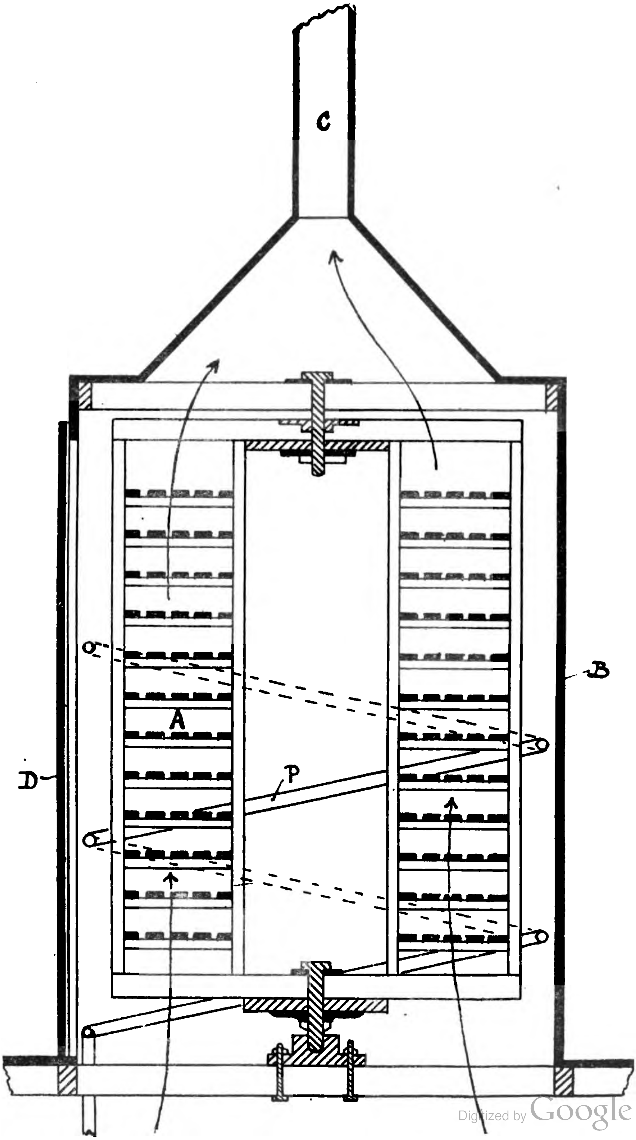
The only recognised special dryer of this kind is one in use in French faïence works and illustrated in Figs. 49 and 50. It takes the form of a rack A, circular on plan, which can be rotated on its axis and which is enclosed in a cylindrical casing B only sufficiently large to admit of the rack and the heating pipes.

A sliding door D at one point of the cylinder gives access to the rack, all parts of which may be in turn reached by rotating it on its axis.

A spiral steam pipe P next the casing provides the heat for drying, and a central chimney C creates a current of air through the system from below upwards.

The rotation of the rack is only for the purpose of bringing all parts of it opposite the door and has no bearing on the drying process.

Several of these racks may be enclosed, if desired, in one cylindrical chamber. Each one then rotates on its axis and all are placed symmetrically about a central pivot. In this way each rack may be brought opposite the door of the casing and may be itself revolved so as to present all parts of it to the opening.


C
B
A
P
D

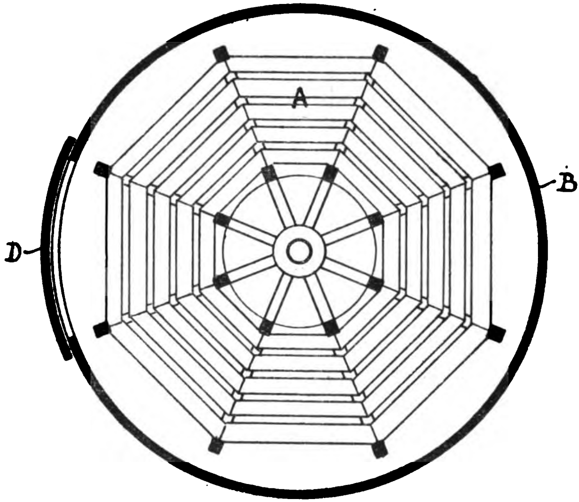


FIG. 50.

2c. Dryers provided with detached heaters and ventilating chimneys or flues.

This sub-division differs from the preceding in the employment of detached heaters. A dryer of this kind takes the form of a shed provided with racks, and may have one or more floors. It is closed hermetically, with air-tight doors for access, and the required movement of air may be obtained by means of tall wooden chimneys or ventilating fans. The disposition of heaters and ventilators may take any desired form, and Figs. 51 and 52 show a convenient method of arrangement which has proved efficient in practice.

A two-storey shed with a latticed floor is racked throughout transversely, A. At one end is a tubular steam heater shewn at B, Fig. 52. Air is drawn from without through the tubes of the heater, through the flues C and the openings D near ground level within the shed. It traverses the racks, rising partly through the lattice floor into the upper storey and finally is discharged into the outer air by the two fans F, Fig. 51, on opposite sides of the shed and at different levels.

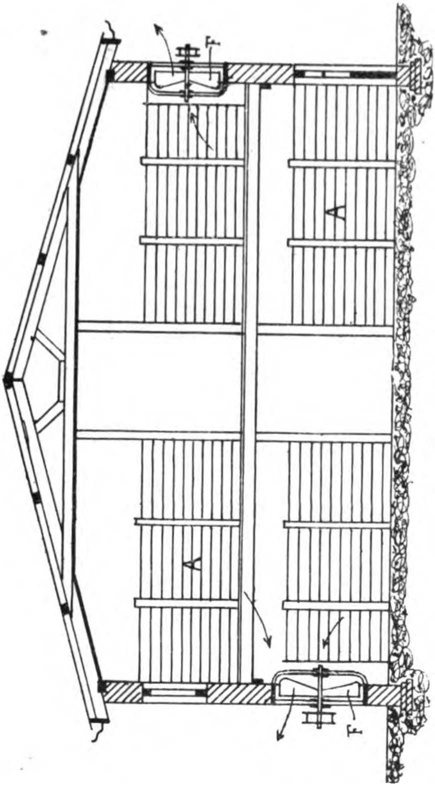


FIG. 51.

This arrangement, though fairly efficient, is of doubtful value and has several drawbacks. It works solely on the "convection" principle, the air carrying all the heat provided for the drying. A large volume therefore has to be passed through the shed mechanically, absorbing power and creating unequal draughts which are difficult to control.

Drying cannot be performed in such an arrangement more rapidly than in a simple shed, provided with racks, steam pipes, and simple aëration.

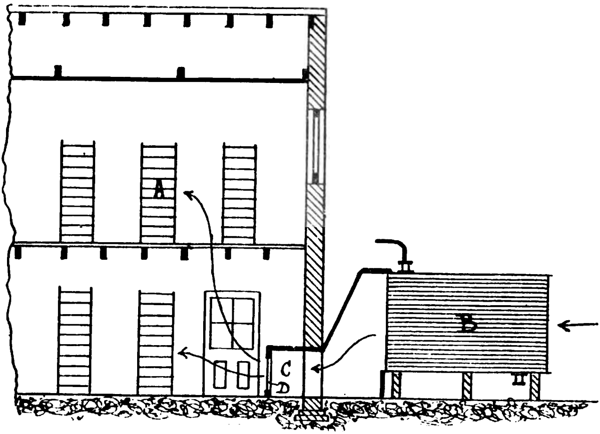


FIG. 52.

2*a*. *Dryers with isolated chambers or tunnels, ventilated and used intermittently.*

There appears to be but one practical invention among dryers which is constructed and functions in the same way as a continuous brick-burning kiln, and which at the same time is worked independently. Hardly any of the modern tunnel dryers which come under the third main sub-division make any attempt to recover the heat given off by the dry bricks as they issue from the tunnels, and it will be seen later that this heat is not an item to be disregarded.

WEIGELIN.

The invention of Weigelin of Stuttgart, however, does actually effect this recuperation and may be considered one of the most efficient as well as one of the most carefully designed dryers working on the radiation principle. At the same time it cannot compete actually with the more modern dryers for several reasons, chief among which is the cost of labour in working it. In construction, it takes the form of two rows of chambers *a*, Fig. 53, four or more in each row, with an accessible passage *b* between them. Each chamber has a hatchway in the outside

wall, for the purpose of introducing and withdrawing the goods, and this is bricked up and plastered exactly as in a kiln.

Fire is lighted in one furnace *c* and the products of combustion pass through the flues *d* under the floors and upwards in the side walls, issuing above the goods stacked in the chambers. They then pass either over the goods or partly over and partly down through the goods and enter the next chamber through the opening *i*, travelling over the goods in it, or both

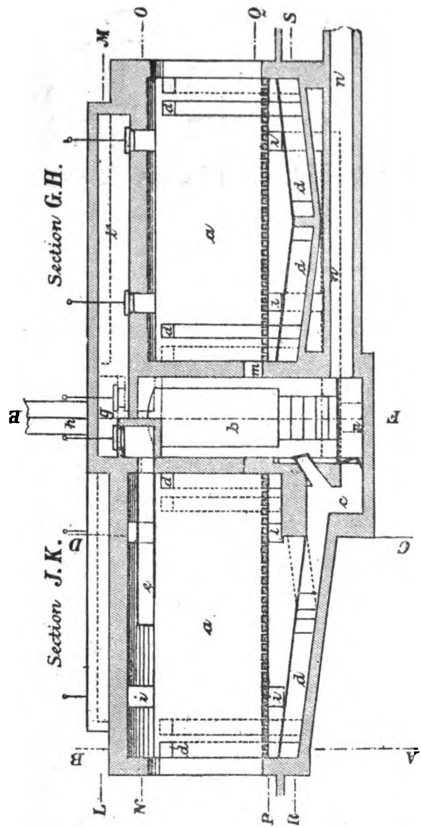


FIG. 53.

over and through them, leaving the chamber by way of the ceiling flue *e* to the main flue *g* and chimney *h*.

The next chamber, which may be numbered III. (No. I. being the chamber heated by fire direct and No. II. by the products of combustion escaping from No. I.) is heated by air warmed by the dried goods in No. VIII. This second circuit is formed as follows :—Cold air enters through flue *n* into the middle passage *b*, passes into the cooling chamber VIII. through

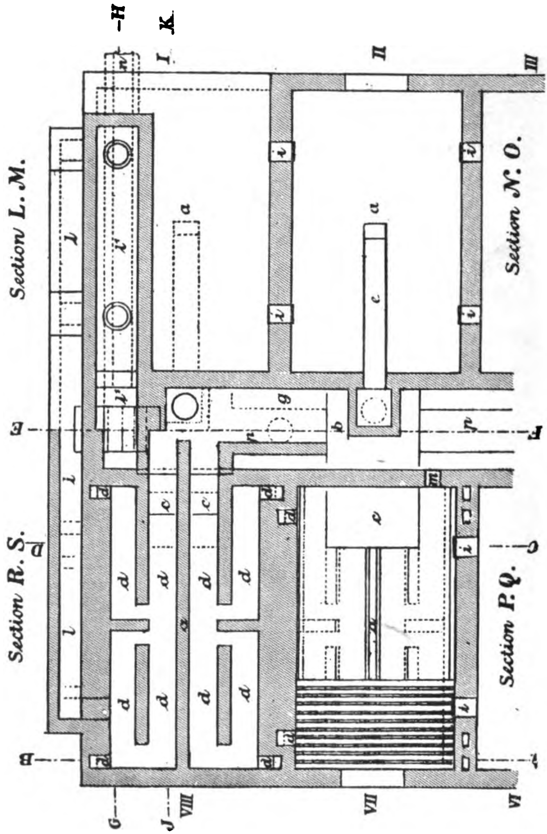


FIG. 54.

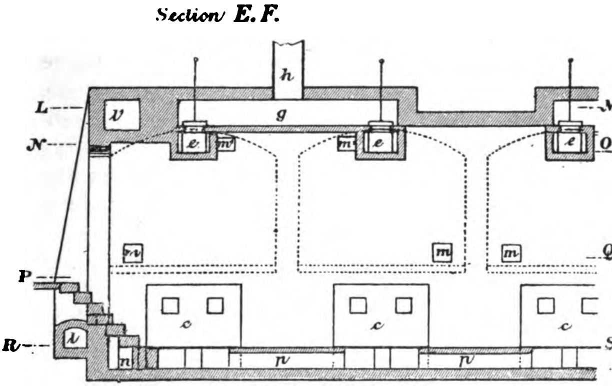


FIG. 55.

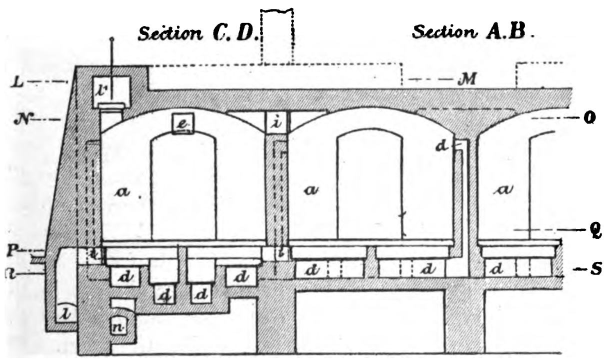


FIG. 56.

opening *m* near the ground, rises through the hot dry bricks and passes again into *b* by the top opening *m'* in No. VIII. The corresponding opening *m'* in No. III. is open and the hot air enters this, passing *over* the wet bricks and into the channels *d*. It now flows through the furnace *c* of the same chamber into the flue *p* under the floor of *b* and serves as air for combustion of the furnace in activity which is heating No. I.

This ingenious but somewhat complicated operation is not easy to follow. The effect, however, obtained when tender goods are being dried may be so arranged that the drying media, whether air or products of combustion, pass only *over* the goods and not through them, thus acting as means of carrying off moisture only, the heat for the actual drying being provided by radiation from the dryer walls and floors. The volume of these media also, as may be gathered from the description, is very small, whether passed through the goods or not. By reason of this a minimum of heat is wasted by the saturated air which carries off the moisture.

This dryer which was introduced in 1891 is considered by German experts one of the most efficient invented, but it is evident that it is by no means easy to manipulate and is theoretically rather than practically good.

The Figures 53 to 56 will be understood from the preceding description, it being necessary only to note further that the end chambers communicate by means of flues *l* and *l'*, and the ashpits of the furnaces *c* are all in communication by means of flue *p* under the passage floor.

JUNG.

In the invention of F. H. Jung, of Salisbury, introduced in 1893, a Hoffmann kiln is provided with six extra chambers, making twenty in all. In this way provision is made for the use of five chambers at a time in the circuit for drying soft made goods on cars. Five days or more are allowed in this way for the drying process and the goods can then be set in the adjoining empty chamber without further transport. The air for drying is heated in the tubes *a* under the kiln floors (Fig. 57), and also in the elaborate system of flues *e*, *f*, *h*, *l* above the kiln arches. It is drawn downwards and into the main flue *q*, through the flues *c*, *c'* by the chimney draught. No heat is abstracted from cooling bricks in the chambers in this invention, so that it is only heat which would descend into the ground or radiate into the air through the kiln walls, which is made use of. Calculations already given (p. 93) shew that this heat is not sufficient in quantity to dry enough bricks to

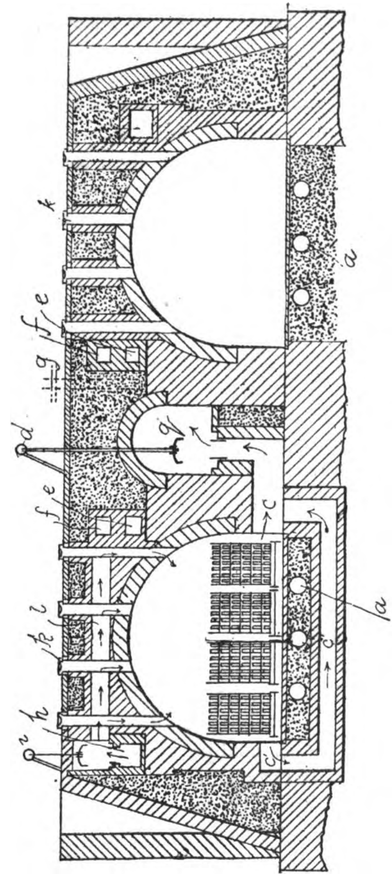


FIG. 57.

supply the kiln. It is evident also that the cars in the chambers will not hold so many bricks as the chambers themselves when set for burning, so that the point for consideration is, whether the cost of the extra chambers is rendered advisable by the output of dry bricks obtained.

PETERBOROUGH.

This invention is on somewhat similar lines to that in practice in Peterborough, where some five or six chambers have wicket fires for the purpose of drying the bricks, which are made stiff enough to bear at once the weight of others stacked on them in the chambers. In this case, also, the waste heat of cooling or radiation from the kiln would not suffice to dry the goods, although the contained water is comparatively small in amount, and this is the reason why wicket fires are used for the drying and "advance drying" flues are not found suitable.

This method of drying is the most economical possible in cost of labour and fuel, for the bricks are but once handled, and when dry and warm are not again cooled before being burned. One pound of coal suffices to dry about 5lbs. of water out of the bricks.

A small opening about 9ins. square is made at the bottom of the brick and clay filling-in of the wickets or hatchways. Each chamber is separated from the adjoining ones by a partition either of paper or of brick. If of brick, openings controlled by dampers are provided, to allow of the passage of the kiln gases when the bricks are dry. If of paper, the paper is destroyed in due time by the advancing heat of the burning. The dampers of the chambers to be dried being opened, small fires are lighted against the holes in the wickets, and the draught caused by the chimney draws into the chambers the products of combustion, largely diluted with air. The heat thus introduced is not sufficient to damage the newly-made bricks. A small fire suffices burning from 2 to 3 cwt. of coal per day, and it is usually kept going for six days before the chamber is included in the burning circuit of the kiln.

The other chief kinds of dryers included under this head are in tunnel form and used intermittently. They differ from the Keller dryer, described on page 91, chiefly in the provision of ventilating appliances, either in the form of chimneys or fans, and the chief difficulty which has arisen in practical work has proved to be the regulation and distribution of the ventilation, so that all the goods in one tunnel are dry at the same moment.

The home of the tunnel dryer, whether continuous or inter-

mittent, is America, and it is thence that come most of the successful forms.

ARNOLD.

The invention (1890) of P. Arnold, of Canal Dover, Ohio, is provided with a tall wooden chimney at one end for ventilation, and with steam pipes under a latticed floor for the source of heat.

Below the pipes are air inlet flues with graduated perforations for admitting air.

The dryer consists preferably of three tunnels, so that one is closed for drying while the other two are in process of emptying and filling.

Flues in the ceiling, with specially designed inlets from the tunnel, serve to conduct the moist air from all points to the chimney. The goods may be placed on cars running on rails, or simply stacked on one another, or on cradle pallets in the tunnels.

AMERICAN CLAY WORKING CO.

A more recent and successful development of this system is that of the American Clay Working Machinery Co., of Bucyrus, Ohio, which is illustrated in Figs. 58 and 59. Fig. 58 is a perspective view, and Fig. 59 a cross section.

Six tunnels B are shewn, enclosed in thick outer walls A and separated by wood partitions.

Under the roof *a* are spaces C, which communicate with the tunnels by means of flues or pipes d'.

Heat passing through the ceilings of the tunnels warms the air slightly before it descends the flues d'.

When the air reaches the tunnel floor it passes over steam pipes *d* (shown only in the two right-hand tunnels).

Flues D, which are extended upward in the form of small wooden chimneys, serve to carry off the moisture-laden air, which is admitted to them by controllable openings *f* and *g*. The number of flues D and d', and of openings *f* and *g*, is determined according to circumstances in each individual case. The number of steam pipes also may be varied, and some as shewn in Fig. 59 may be placed at the sides as well as at the bottom of the tunnels.

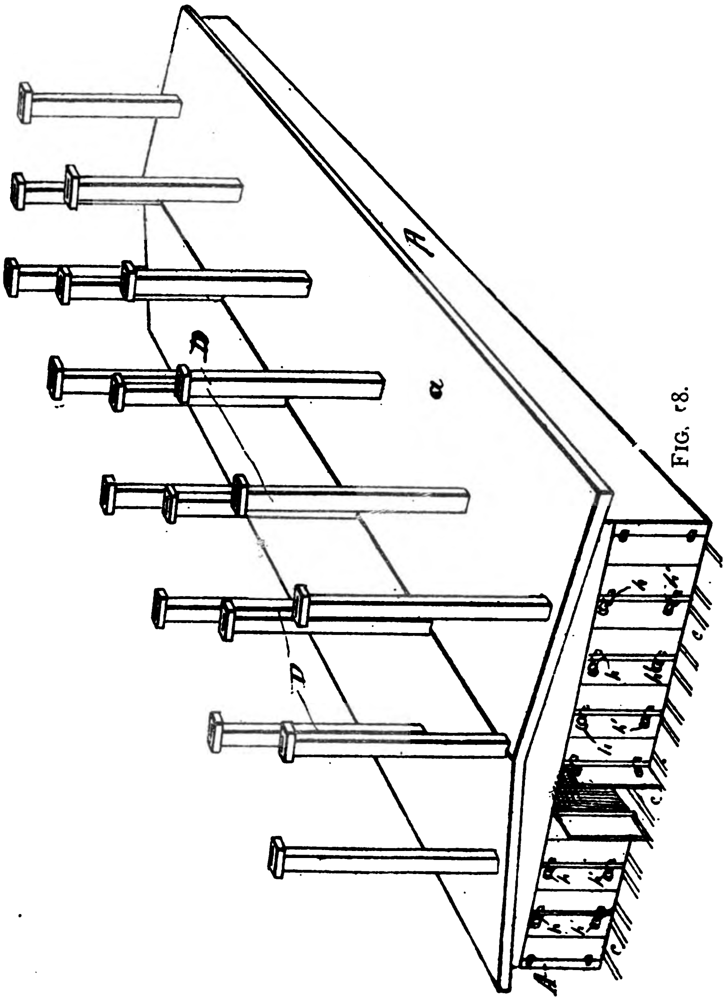


FIG. 58.

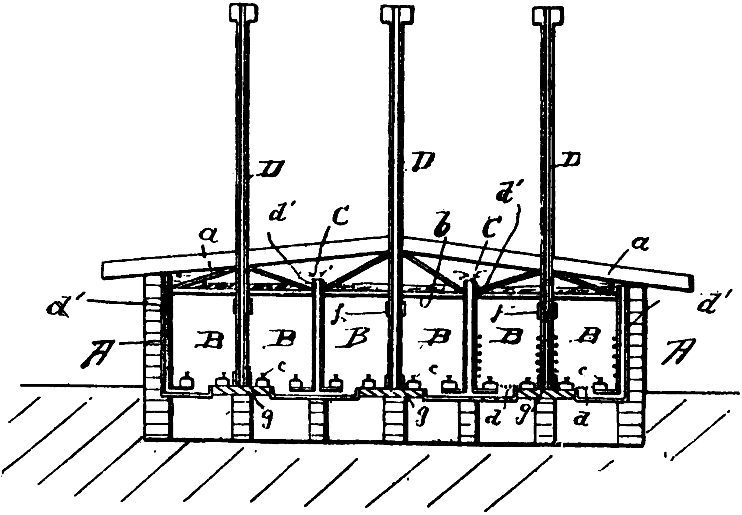


FIG 59.

Cars are introduced on the rails *c*. At the entrances to the tunnels in Fig. 58, will be noticed handles *h* and *h'*, which are connected by means of long rods with the regulating covers of the moist air outlets *f* and *g*. These can thus be controlled at will from outside.

This dryer may be considered a simple and efficacious solution of the practical difficulties which arise with Keller's dryer. The rack and barrow system could well be applied to it in place of the more costly brick cars, and the dryer would then probably be as cheap in first cost and as efficient in practice as any that could be designed for working intermittently and drying tender goods, which must be allowed more than 48 hours in the process.

An advantage not indicated by the inventors might be obtained by warming the air supply to the tunnels in action, by passing it over the hot dry bricks in tunnels just dried. This recuperative action is not apparently indicated in any intermittent drying system except that of Weigelin, described

above. It would render the tunnels more comfortable for workmen to empty, as they are usually very hot when first opened.

The suitability of this dryer, as well as of Keller's and of some of the open shed forms for drying tender clays, is due to a judicious combination of the two principles of radiation and convection. A tender clay will permit of heat being supplied to it by radiation much more rapidly than by conduction or convection, and by restricting the aëration to the lowest quantity possible, at the various stages of drying, to ensure carrying off the moisture evaporated, rapid drying without cracking can be accomplished.

The fact that the clays found in greatest quantity are usually easy to dry may perhaps account for the fact that dryers of this type are few in number in comparison with those working solely (or nearly so) on the convection principle.

Of this latter type, two forms may be here noticed, on account of the ingenious devices employed, before proceeding to the description of the modern progressive tunnel dryers.

SCHEIDWEILER.

The construction of Scheidweiler of Dortmund (Germany) is characterised by a means of reversing automatically the direction of the hot air currents in the tunnels so as to ensure the simultaneous drying of the goods in them.

Fig. 60 shews in diagrammatic form the plan of a series of tunnels, A. At B is the source of heat, which may be of any desired form, such as a steam air-heater, coke air-heater, or direct furnace supplying diluted gases of combustion. At C is a chimney or fan providing the requisite suction of the air or gases through the tunnels. D is a supply flue with valves *d*1 and *d*2 at its extremities connecting it with flues E1 and E2, which extend across the ends of all the tunnels.

Apertures *e*1 and *e*2, with controlling valves, open from these into the tunnels at the floor.

At the chimney side of the tunnels is a flue F with valves *f*1 and *f*2, also communicating with the service flues E1 and E2.

It will be seen that if the valves *d*1 and *f*1 are open at the

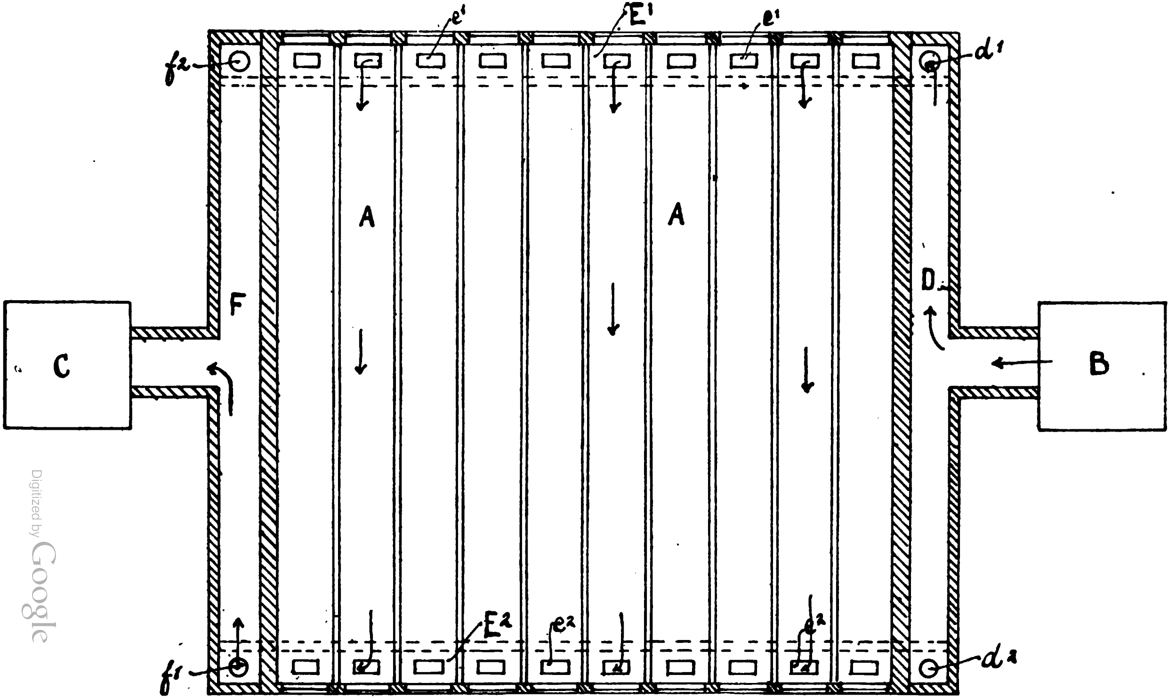


FIG. 60.

same time the current of hot air or gases will follow the direction of the arrows, whereas if *d*1 and *f*1 are closed and *d*2 and *f*2 are open, they will travel in the reverse direction. By reversing frequently the direction of the currents, simultaneous drying of the goods in the tunnels will be ensured. The goods may be stacked in the tunnels in any desired manner.

The regular and frequent reversal of the currents is obtained by means of a water oscillator connected with the valves *d*1, *d*2, *f*1 and *f*2. The principle of this is shewn in diagram in Fig. 61.

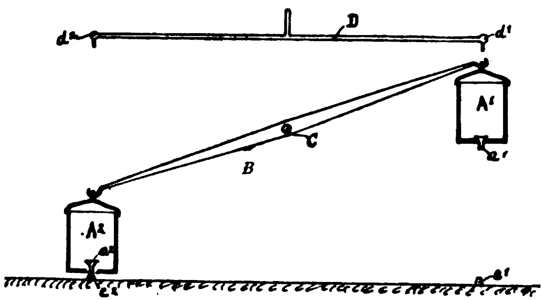


FIG. 61.

Two buckets, A1 and A2, are swung on a beam, B, pivotted at C. At D is a water service pipe with taps, *d*1 and *d*2, so placed that they are directly over the buckets in their highest positions.

In the bottoms of the buckets are valves, *a*1 and *a*2. At *e*1 and *e*2 are studs placed directly under the valves *a*1 and *a*2, when the buckets are at their lowest positions. The spindle at C on which the rod is pivotted is in connection with levers which actuate the valves of the dryer and the taps of the water service pipe.

Suppose, now, the apparatus be in the position shewn. The valves of the dryer *d*1 and *f*1 (Fig. 60) are open and also the tap *d*1, of water service. Water gradually fills the bucket A1, and when it is full the friction of the system is overcome by the weight of the water in the elevated bucket, so that it descends reversing the dryer valves, closing the tap *d*1, and opening the tap *d*2. The valve *a*1 also strikes on the stud *e*1

causing it to open and permit the escape of the water in the bucket A1. The currents of hot air or gases in the tunnels are now reversed during the filling of the bucket A2, which, when full, in its turn descends, bringing the whole system to its first position. The taps *d*1, *d*2, and the valves *a*1, *a*2, should be adjusted so that the filling and emptying proceeds at the same rate.

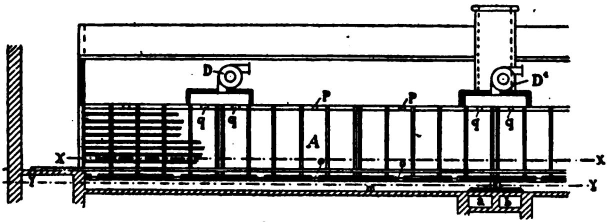


FIG. 62.

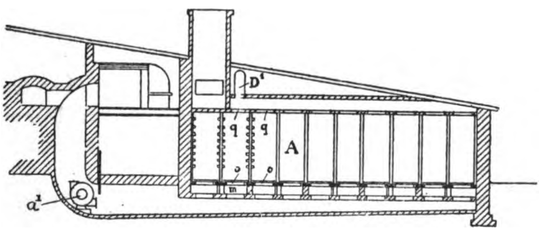


FIG. 63.

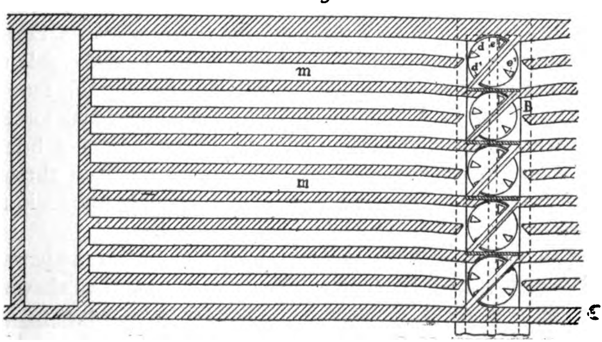


FIG. 64.

VILLARET & WAHLEN.

The system of Villaret & Wahlen, of Cologne, shews a combination of devices for equally distributing the hot air currents and also for graduating the intensity and dryness of them.

Fig. 62 is a longitudinal section, Fig. 63 a cross section through the flue *a*, and Fig. 64 a plan on the line YY.

Tunnels A, filled with bricks as in Keller's system by means of a car (shewn in Fig. 65), have longitudinal flues *m* beneath with openings *o* at intervals into them through the floor.

The flues *m* are served with air by the transverse flues *a* and *b*, one for hot and the other for moist cool air.

The adjustment of this supply is made by valves B (Fig. 64), by means of which moist cool air can be admitted with a small addition only of hot dry air at first. By revolving the plate B, more hot and less cool air may from time to time be admitted to the flues *m*. In this way gradual drying is obtained at first, which is accelerated as the progress of drying advances and the bricks become less sensitive.

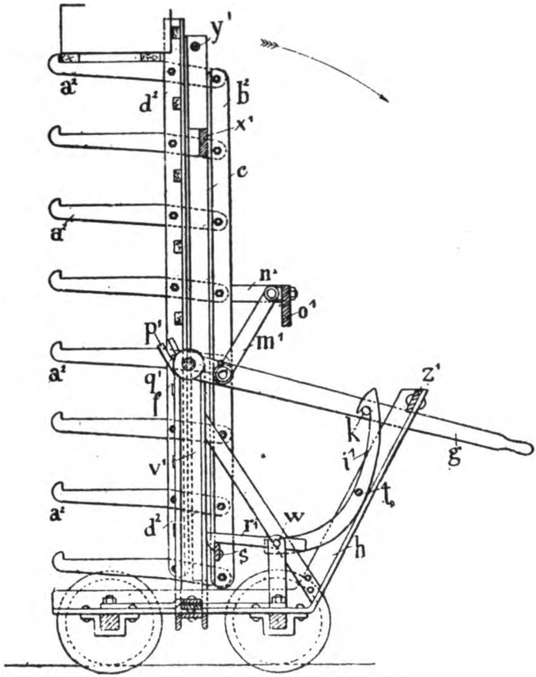
In the figure 63 the fan *a* 1 supplies flue *a* from the chambers over the tunnels, into which the cooler and moistened air escapes from them after doing its work. A similar fan supplies the flue *b* from an air heater of any desired form.

The inventors further provide fans at D and D 1 into cross flues which communicate with the tunnels by openings *q* in the ceiling.

Air entering the tunnels at *o* rises through the bricks rapidly to the top and passes through *p*, but in order to make full use of it a portion is driven down again through *q* by the fans D and D 1. This is done to counteract the ascensional force of the warm air and ensure the drying of the lower tiers of bricks.

The surplus air, equal in quantity to that supplied through flue *b* from the heater, escapes by the chimney shewn in the figures.

In connection with this system the inventors use a rail barrow, similar to that used by Keller. This one, however, as shewn in Figs. 65 and 66, is contrived for a further purpose. When loaded with *dried* bricks the whole frame can be tipped back


y'
a²
d²
b²
x'
c
n'
o'
p'
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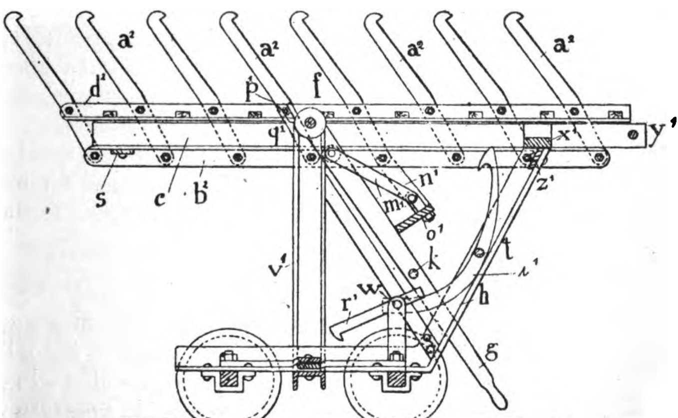
h

FIG. 65.


a²
d²
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q¹
y'
x'
s
c
b²
n'
z'
m'
o'
v'
k
t
r'
w
h
g

[FIG. 66.

on the pivot *p*, by means of the lifting-lever *g*, and the barrow will then enter the ordinary kiln wickets without difficulty.

The barrow is also intended to be loaded direct from the machine instead of with an intermediate rack, and several ingenious variations of form have been devised to facilitate loading.

These last-described dryers are worked intermittently and on the convection principle only, and though ingeniously designed to overcome the difficulties of unequal drying are open to the objection of all the systems described under this head which are strongly ventilated.

It is evident that as the bricks become more and more dried a successively larger quantity of heat must be wasted by the escape of hot air only partially charged with moisture. This result is inevitable with any *rapid* drying system which works intermittently. The objection, however, does not hold in the case of the systems of Keller and the American Clay Working Machinery Co., because the aëration or ventilation is slight and in the latter system may be reduced as drying progresses, so that very little heat is lost with the escaping air. The rapidity of drying, however, is less in consequence, and a period of four days must on an average be allowed.

Some progressive systems will dry successfully the most tender clays in half this time, or even less, but they are, as will be seen later, more costly to install, and it is a matter to be determined by the individual clayworker whether the intermittent or progressive form is best suited to his particular requirements.

It may, however, confidently be stated that the two systems above mentioned are reliable, efficient and economical for use in the drying of tender clays which crack easily, and will not bear strong air currents.

CHAMBERS.

Before leaving this section, mention should be made of the dryer of Chambers, of Philadelphia. It is illustrated and described in some important works on brickmaking, but it is now practically obsolete. It is in tunnel form, with an iron floor on which the car track is laid. A grate is constructed

under the floor of each tunnel, and the products of combustion, mixed with a considerable volume of air, rise through occasional openings in the floor into the tunnel. A chimney at the end produces the required draught. The dryer is intermittent in action, inefficient in comparison with progressive dryers, and cannot be used for any but the most easily dried and commonest of clays.

CHAPTER VI.

III.—Dryers Warmed and Ventilated with the Goods Moving and Drying Progressively.

This modern form of dryer, which, as a general rule, works on the convection principle, has been developed in Germany and America, and it is remarkable how little inventive genius has been applied to its perfection in this country. It is the form which effects the greatest saving in labour, so that its use is becoming more and more imperative as labour becomes scarcer and dearer.

The labour difficulty accounts for the development of the system in America. In Germany, on the other hand, labour is cheaper than in England, and the use of tunnel dryers is but occasional, those most in vogue being of a very expensive type of construction.

a. *Dryers ventilated in the reverse direction to that in which the goods move.*

Before describing the progressive tunnel dryers and discussing their mode of working and efficiency it will be convenient to give a description of several dryers of this type which are not strictly speaking independent tunnel dryers.

The sub-division might be further split up into classes indicative of the system of heating adopted. In general, how-

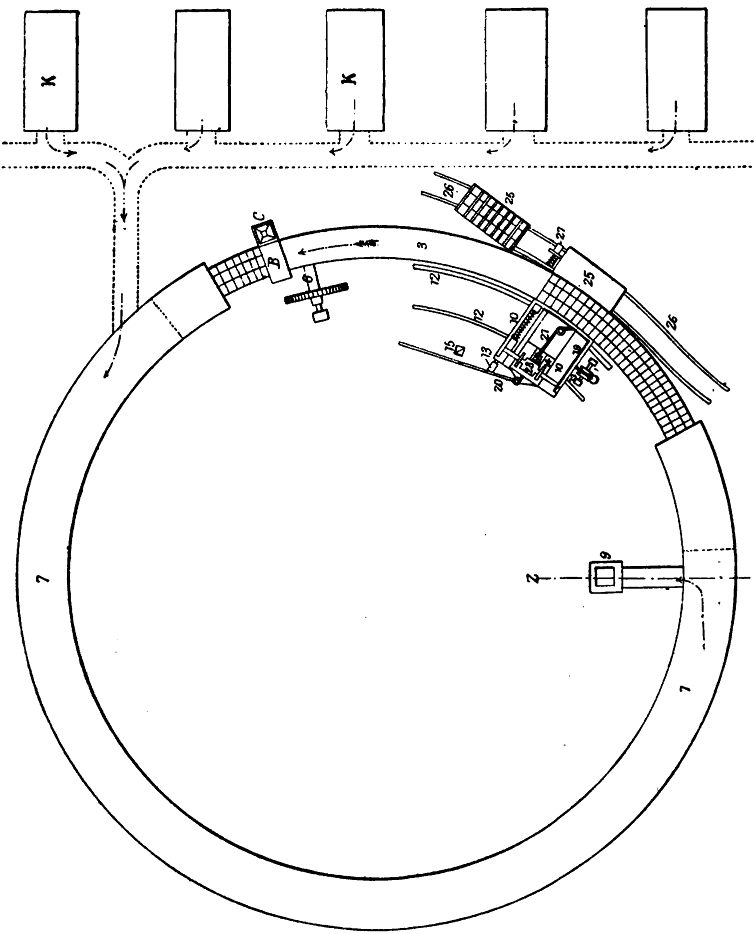


FIG. 67.

ever, all inventions coming under the present heading may be supplied with heat in a variety of ways, and it will be better to study them from the point of view of form.

BLAND.

The annular form has little to recommend it in consequence of the mechanical difficulties of construction and provision of motive power. The invention of P. E. Bland, of St. Louis, so far back as 1867, however is worthy of notice, as it is among the earliest invented progressive dryers.

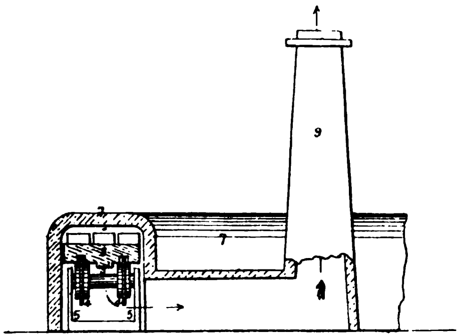


FIG. 68.

Figs. 67 and 68 shew its form in plan and cross section.

A revolving annular table 500 feet in circumference is carried on anti-friction rollers and is moved by a rack and pinion device. The brickmaking machine deposits three bricks at once on the table by an ingenious automatic arrangement, so that no labour is expended from the time the clay is dropped into the hopper till the dry bricks are ready for wheeling to the kilns. The output of this apparatus is evidently quite inadequate, and quite out of proportion to its cost of installation.

In Fig. 67, B is the brick machine, 7 the annular tunnel, 3 the moving table and 9 the chimney, while at 25 is seen an automatic discharging device for delivering the dry bricks on to the kiln cars. The hot-air current, taken from cooling kilns K, is passed in at the same point as the wet bricks and travels in the same direction. It may, however, be passed in the opposite

direction, says the inventor, which is obviously the correct and only efficient way in which it could be used in practice.

Fig. 68 is a cross section on line z z.

COLUMBIAN POTTERY CO.

An annular drying arrangement in connection with a brick burning kiln, with revolving annular floor, was patented in 1894 by the Columbian Pottery and Brick Kiln Co., of Chicago. A great deal of ingenuity is shown in the design of this kiln, but the drying portion of the arrangement is subsidiary, and does not call for illustration or description.

STURM.

A more elaborate and carefully worked out circular dryer is that of Henri Sturm, of Paris, patented in 1898. It is designed for drying ceramic ware, and is capable of a considerable output, but as will be seen from the figures (69 and 70), it is not a labour-saving device in the sense of the progressive tunnel dryer. The goods, after being conveyed to it, must be twice handled before reaching the kiln in the dry state, labour which is entirely avoided in the tunnel dryers.

Fig. 69 is a plan, and Fig. 70 a section on the line O P Q R. The outside diameter is about 55ft., and it is divided into twenty sections each about 8ft. by 6ft. by 9ft. high, provided with shelves, on which the goods are placed. The framework, carrying the revolving platform, is pivoted at the centre, and runs on conical-shaped rollers which travel on rails.

A fan delivers air through a tubular heater, 19, shown in the drawing as coke-fired. The heated air travels through an outer flue, 18, with three controllable inlets, 17, into the drying chambers. It leaves the dryer by the chimney 21, into which the gases of combustion are also led by a flue-pipe. The outer wall, 11, and ceiling 3 are fixed, while the inner wall 2 and platform 1 move with the chambers, and an air-tight seal is made by a sand groove 15, and curtain 37. At 16, an opening in the outer wall provides means of access for loading and unloading the goods. A dryer of this size would be capable of an output of about 25,000 bricks per day, or a correspondingly large quantity of ceramic ware.

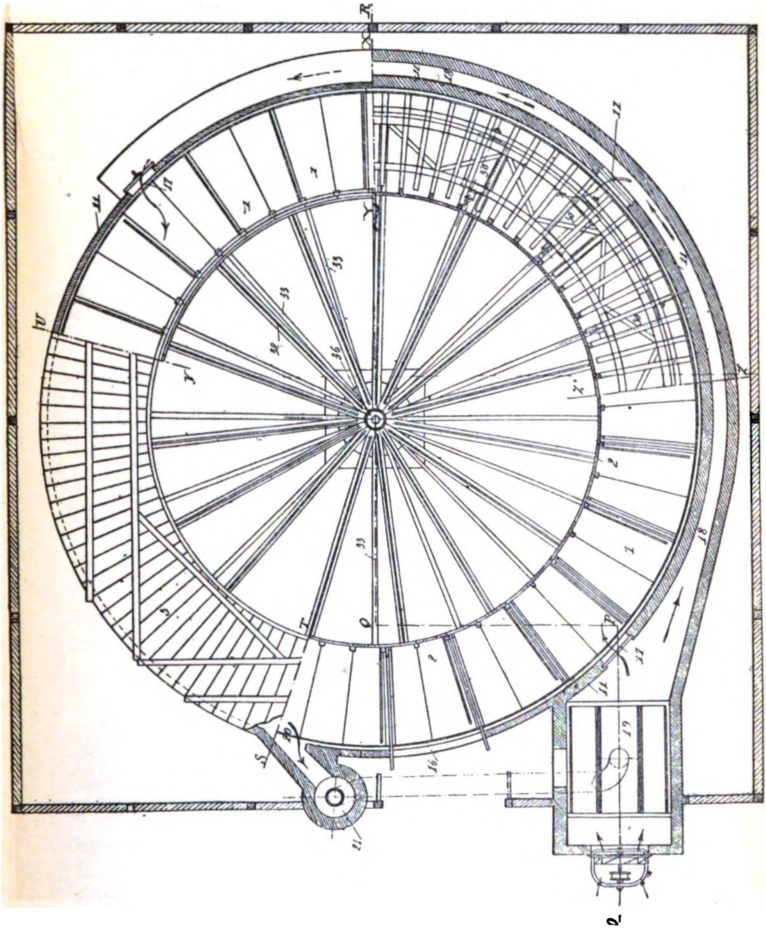


FIG. 69.

Progressive dryers in combination with continuous kilns date from 1884, but in order to treat of all progressive tunnel-form dryers together, a form perfected in 1890 may be better described at this point.

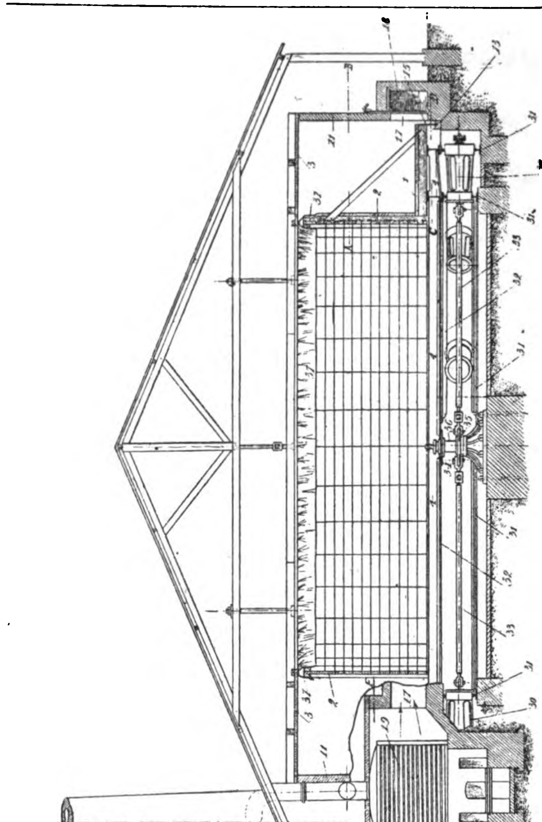


FIG. 70.

SCHAAF.

The invention of Schaaf, of Halle, in Germany, may be installed over a Hoffmann kiln in the way described in connection with section II.a of the sub-division, or it may be constructed

quite independently and supplied with heat by means of steam or hot-water pipes. It is probably unknown in England, but it has many features to recommend it, and is considered by German experts to be one of the most efficient brick dryers known.

It may be conveniently described as consisting of a range of pigeon-holes, each large enough to admit a green brick on its pallet. The pigeon-holes are inclined so that the bricks slip down them to the lower extremity by gravitation. At the bottom of the slide is a straight length which serves to arrest the slipping process, so that each pigeon-hole is filled with bricks which remain stationary till the bottom one is removed.

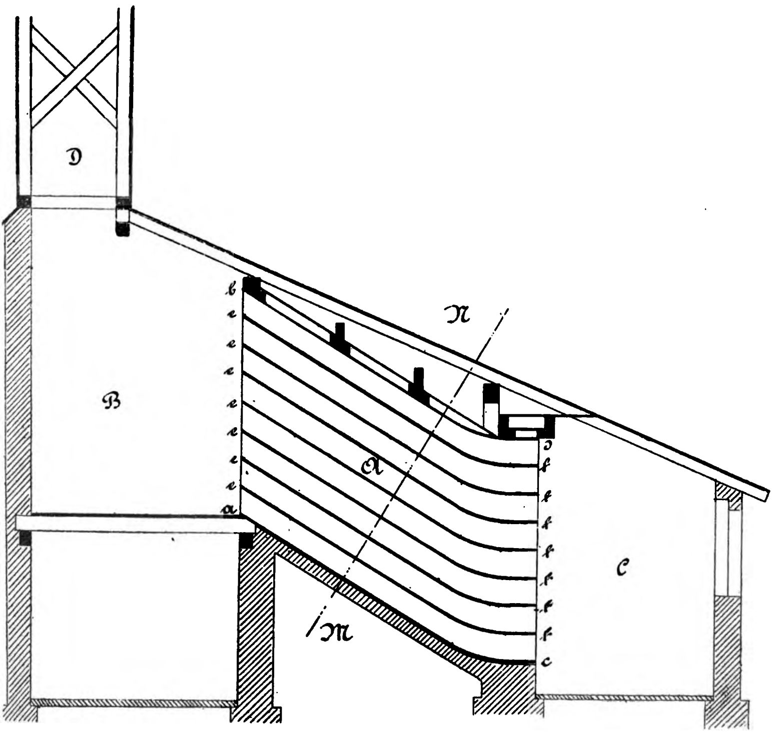


FIG. 71.

A current of warm air ascends each pigeon-hole, and in its progress absorbs moisture from the bricks, which, entering wet at the top, are dried by the time they reach the bottom of the slide. The ascensional force may be provided by a fan or chimney.

Fig. 71 shows in diagram, a section of an independent dryer to which the requisite volume of hot air is supplied from the chamber C. This chamber also serves for collecting the dry bricks at the point *f*.

The air ascends through the pigeon-holes A, passing out of them into chambers B, and thence up the chimney D.

Wet bricks are introduced into the pigeon-holes by way of chamber B, and slip on pallet boards from *e* to *f*.

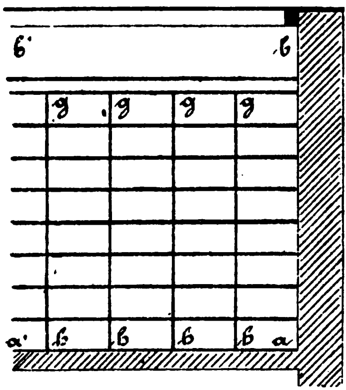


FIG. 72.

Fig. 72 is a part diagrammatic section of the pigeon-holes on the line M N.

Fig. 73 shews in longitudinal section the construction adopted when steam or hot water pipes are used for heating the dryer. The pigeon-holes are larger and each serves for the passage of three or more tiers of bricks, the pallets carrying which slide on side ledges *m n*. The pallets *p* are furnished with light veils *v*, and the horizontal partitions with similar veils *w*, to compel the air currents to pass closely along the surfaces of the bricks.

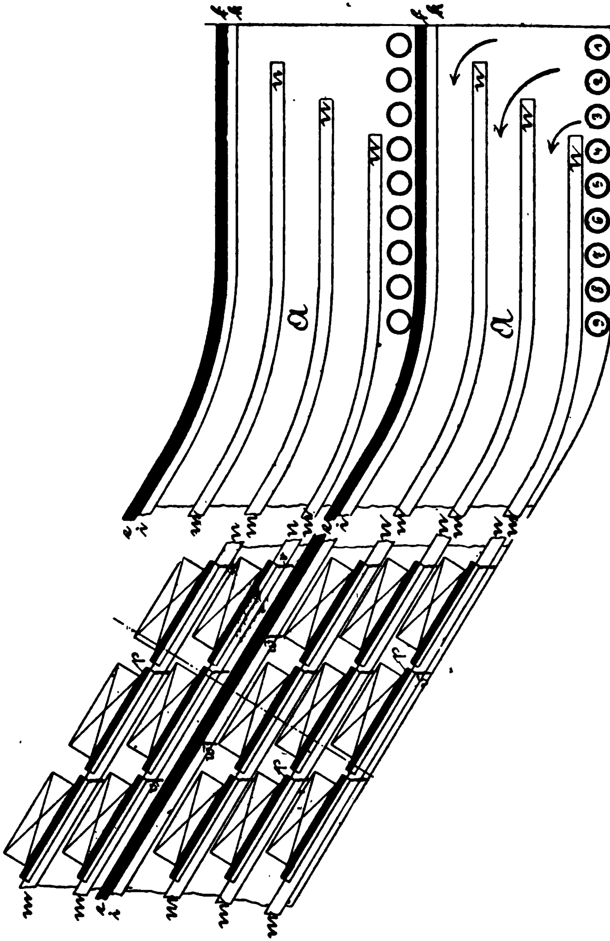


FIG. 73.

Fig. 74 shews the dryer applied to a Hoffmann kiln. This figure explains itself, and it is only necessary to note that the lower ends of the horizontal partitions are perforated in a manner calculated to distribute the air currents equally to all the pigeon-holes.

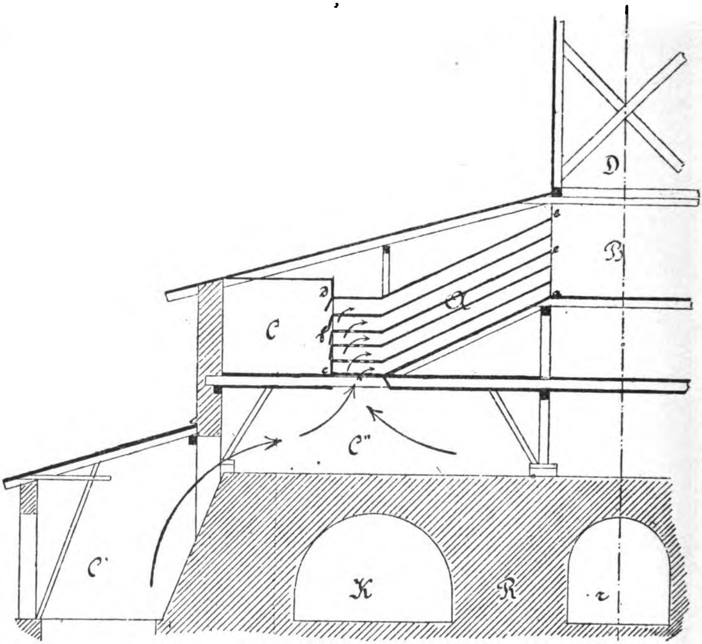
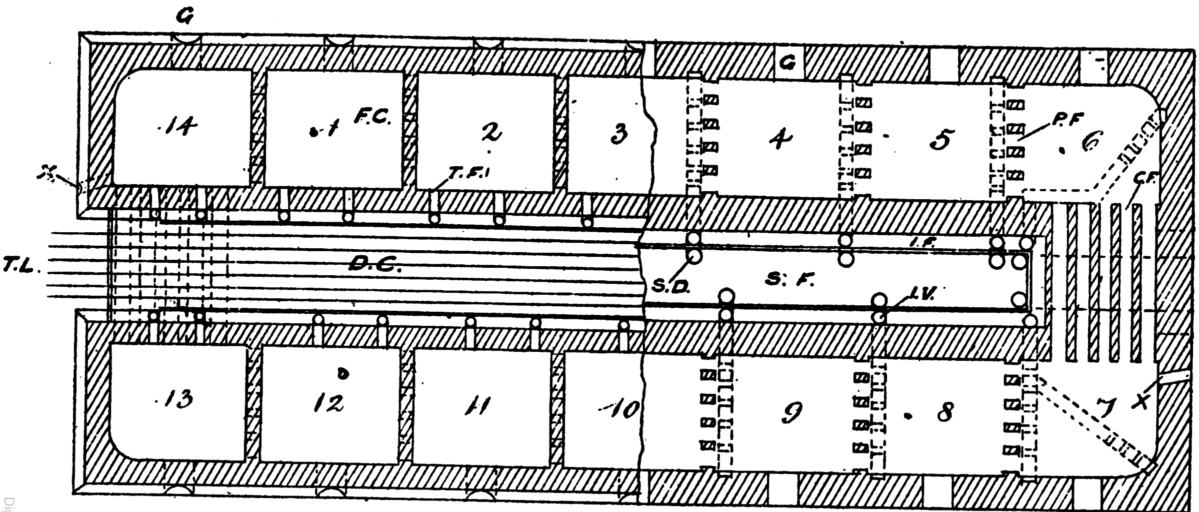


FIG. 74.

The claims of this dryer to efficiency are : (1) that the air for drying is split up into many independent currents which are compelled to come into very close contact with the goods and yield up all their available heat ; (2) that very little heat is lost by radiation from the walls. A dryer of this form has three times the capacity of a racked shed, and in practice one 120ft. long by 65ft. wide will yield an output of 20,000 bricks daily if heated only by day, and of 30,000 daily if heated at night also.

It is said to give superior results, compared with the other forms described under section **II. a,** when installed over Hoffmann kilns.

Tunnel-form dryers, in which the bricks are passed on cars through a tunnel constructed between the two galleries of a Hoffmann kiln, are in use to a small extent. They do not, how-


G
G
14
1
F.C.
2
T.F.1
3
4
5
P.F
6
C.F.
T.L.
D.C.
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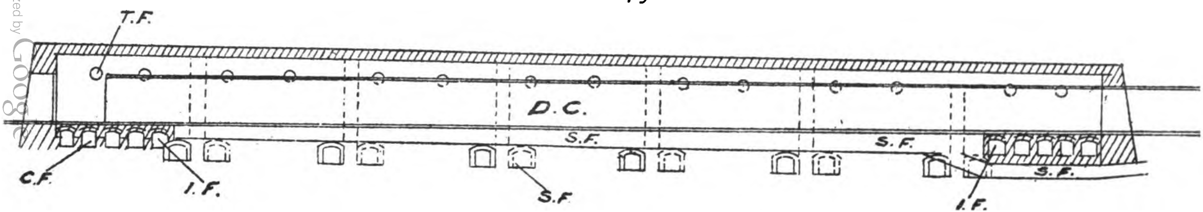
S: F.
I.F.
I.V.
13
12
11
10
9
8
7
X

FIG. 75.


T.F.
D.C.
S.F.
S.F.
S.F.
C.F.
I.F.
S.F
I.F.

ever, give an adequate output, and have several drawbacks in practice.

COOK.

The invention, in 1893, of Richard Cook, of Kensal Rise, Middlesex, has several good features and has the merit of using to some considerable extent the principle of radiation.

Fig. 75 is a sectional plan, Fig. 76 a central longitudinal section, and Fig. 77 a cross section of the kiln.

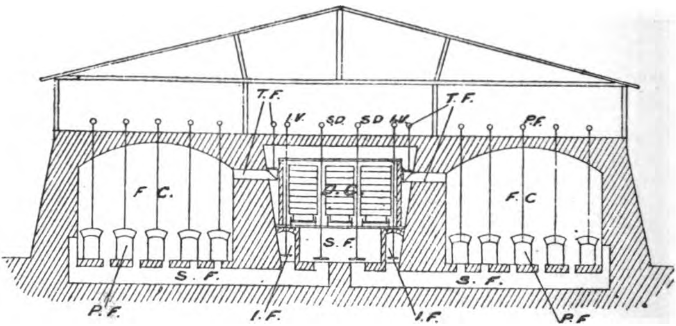


FIG. 77.

Between the two galleries of burning chambers F C is constructed a tunnel D C. At the lower part of this is the smoke flue S F leading to the chimney. It is covered with sheet iron on which are fixed the rails for the dryer cars.

A separate inner tunnel with iron ceiling is formed within the main tunnel, but stops short at one end. Hot air from cooling burned chambers is admitted by openings T F to the jacket between the two tunnels, and at the end where the inner one is stopped short, finds its way into the interior and through the cars.

The flues I F are for use in advance warming of the green bricks set in the chambers for burning.

The iron ceiling transmits radiated heat from the hot air and the iron floor from the hot smoke. It will be seen, however, that the hot air enters the jacket close to the free end for a large proportion of the time, and the smoke very seldom

traverses the whole length of the kiln smoke flue. The walls of the drying tunnel are therefore not uniformly subjected to same conditions of heating. The cooling of the smoke also is not permissible unless a suction fan provides the draught for the burning.

WEIJERS.

In March, 1899, Weijers, of Tilburg, in Holland, patented an arrangement which is an exact copy of Cook's invention, though not so fully worked out in constructional detail.

In June, 1899, again he patented a modification which makes use of an appliance in connection with tunnel dryers, patented two years earlier by an Englishman. This appliance consists of a large sheet-iron tube or tubes conveying the hot products of combustion along under the dryer cars.

These patents (?) illustrate, perhaps, the proverbial slimness of the Dutchman, and certainly the bad methods of the English Patent Office, which grants any application, leaving the patentees to fight out the merits of their inventions among themselves.

Great difficulty is found in this form of kiln in carrying the heat rapidly from one burning gallery to the other, and supplementary fires have to be provided to assist in obtaining this result. There are evidently, therefore, so many drawbacks to this form of construction that independent tunnel dryers are undoubtedly preferable.

TUNNEL DRYERS.

The independent progressive tunnel dryers which come in the present sub-division are the dryers which have met with the most widespread adoption and practical success, and it is perhaps as well to refer to the calculations as to heat absorption and fuel consumption, stated on page 44, and supplement them with further statements of the conditions which obtain in this form of dryer. Before doing so, however, it is advisable to glance at the typical form of such dryers as illustrated in the design, in 1884, of Frederic Hoffmann, the inventor of the well-known Hoffmann continuous kiln.

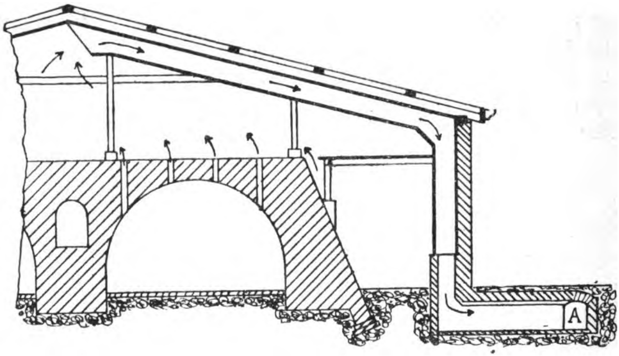


FIG. 78.

HOFFMANN.

The tunnels are placed by the side of and end on to the kiln, and the heat is drawn from cooling burned bricks and the external kiln walls. By means of flues, shewn in Fig. 78, the air heated by these sources is conveyed to the end of tunnels and delivered into them by openings in the service transverse flue A, which is sunk in the ground.

Figs. 79 and 80 shew the tunnels in plan and longitudinal section.

The cars C carrying the bricks to be dried are introduced at the cold end and are moved step by step in the direction of the arrows (shewn outside the tunnel) to the end where the heated air enters from flue A. They arrive here warm and with the bricks completely dried.

The hot air is drawn by a fan in the reverse direction (as indicated by arrows inside the tunnel), and arrives at the end of the tunnel cooled and charged with moisture evaporated from the bricks. It is collected by a transverse flue B similar to the service flue A.

This, then, is the typical progressive tunnel dryer on the inverse principle. The speed of drying, and consequently the output, depends on a combination of conditions of volume, temperature and distribution of air obtaining in each particular case. The speed at which the bricks can be dried, however,

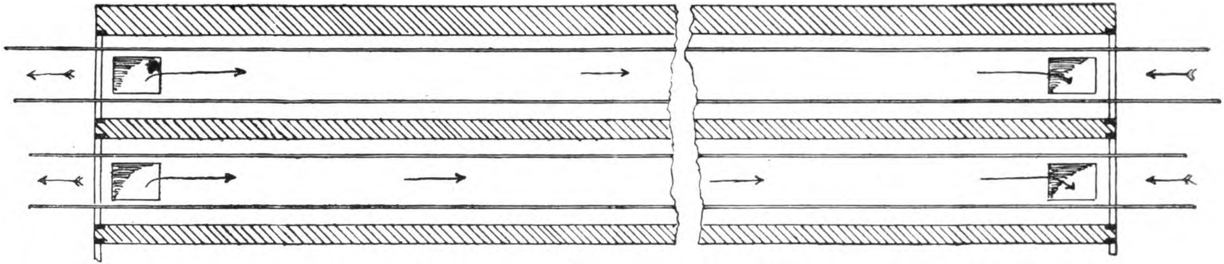


FIG. 79.

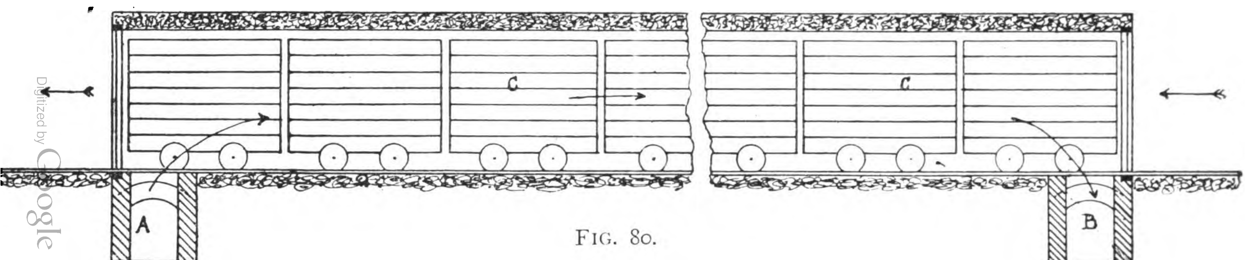


FIG. 80.

depends on an entirely different set of conditions, and the efficiency of a dryer depends on the adjustment of these two independent sets of conditions to each other in every case on its own merits.

As this treatise is intended to be practical rather than scientific, it is not proposed to go into scientific calculations and formulæ in order to demonstrate the processes which take place in this form of tunnel dryer. It will be instructive, however, to examine these processes in a typical case such as can be found exemplified in many manufactories in this country and elsewhere.

A single track tunnel 120ft. long containing 16 rack cars, each capable of carrying 360 bricks, may be worked to dry some clays in 24 hours. This is the same as stating that 16 cars of bricks are dried in that time, which gives a rate of four bricks per minute if the conditions are constantly the same and the dryer is worked with proper attention and regularity.

It was shewn on page 43 that the most efficient practical range of temperature is between 170° and 82° F. for the air entering and leaving the tunnel respectively. It will be observed at once hat the Hoffmann tunnel described as the type could not be efficient because the air would not enter it warmed above 90° or 100°.

The actual temperature of 170° can be maintained in practice by the use of live steam or by exhaust steam supplemented by live steam, and is therefore a practically useful point. Reduction, however, to 82° is not satisfactory because air so far reduced will as a rule part with its moisture too readily when wet cold bricks are first introduced into it. This results in condensation on the bricks even if the air is not saturated with moisture, an effect not easily prevented in inverse system tunnels, but which must be reduced to a minimum. In practice the air is usually discharged at 90° and not saturated with moisture.

Taking the four bricks per minute dried in a tunnel the heat absorbed in the process is as follows, assuming the cars to weigh 540lbs. each, and the bricks when dry 7½lbs. each and the water to be dried out of them 1lb. each.

		B.T.U.*
Heating cars from 50° to 170° = 6lbs.	...	82
Heating clay „ „ „ „ = 30lbs.	...	720
Heating water from 50° to 90° = 4lbs.	...	160
Evaporating water at 90° = 4lbs. ...	...	4,232
Loss by leakage and radiation (say)	...	806
		6,000

The weight of air necessary to yield this amount of heat in cooling from 170° to 90° is :—

$$\frac{6{,}000}{\cdot 237 \times 80} = 316\text{lbs.}$$

The volume of this at 170° F. is 5,000 cubic feet, which is the volume to be supplied to the tunnel per minute, and it will leave it not much more than half-saturated with moisture.

The amount of heat required to warm the air from 32° to 170° is $316 \times \cdot 237 \times 138 = 10{,}350$ B.T.U., which is about the amount yielded by the combustion of 1lb. coal. The transference of heat, however, from the coal to the air through the employment of steam results, if live steam only be used, in a further loss of efficiency, for 1lb. of coal will evaporate say 8lbs. of water at most into steam, which, on condensation in a heater, will yield only 7,736 B.T.U. out of the 10,350 required.

In practice, the efficiency of a steam-heated tunnel dryer may be expressed by saying that 2½lbs. of live steam is condensed in drying 1lb. of water out of a brick. Similarly, it takes at least 3lbs. of exhaust steam to effect the same result, because of the large proportion it contains of already condensed water. It follows from this that 3 cwt. of coal is required to dry 1,000 bricks by means of live steam, and if exhaust steam only is used by day (10 hours) and live steam at night, the coal required is from 1¾ to 2 cwt. per 1,000.

It will be observed that in this calculation as much as 5,156 B.T.U. out of the 10,350 supplied to the air are lost, or a proportion of 50 per cent. The waste by radiation is assumed at 806 B.T.U., or 8 per cent., and that lost by discharging the air at 90° is actually 4,350 B.T.U., or 42 per cent. Herein, as will be seen more conclusively later, lies the weak point of the

* "British Thermal Units," defined on page 5.

inverse system of tunnel drying. A large volume of air must be used, and it must be permitted to carry off a large amount of heat in order to obviate the condensation of its contained moisture on the cold bricks newly introduced into the tunnel.

The devices proposed and employed to counteract this drawback will be noticed in the descriptions of systems in use.

A loss is also incurred of upwards of 7½ per cent. in discharging the cars and bricks highly heated from the dry end, and not again recovering the heat they yield in cooling.

If exhaust steam only is used, the air for drying cannot be heated above 150°, and its efficiency is consequently reduced. It is, therefore, a good practice to use exhaust steam to heat the air as far as the quantity available will serve, and then heat it finally up to 170° or 180° by means of live steam.

Another means of heating the air is by a tubular coke heater, in which the gases of combustion pass over the tubes, and the air is drawn through them. A simple heater of this kind is not to be recommended and is not more efficient than a steam heater. It is also very irregular in its action in consequence of the rise and fall of heat at the grate.

It is the practice in some instances to pass the gases of combustion themselves through the tunnels. This, of course, can only be done when the goods are of a very inferior quality. The products of combustion, which leave the grate at a temperature of 1,500° to 2,000° F., must be diluted with six to nine times their weight of cold air so as to reduce their temperature to about 200°.

The apparatus employed for this purpose will be described later.

In this process the heat calculation becomes the following :—

	B.T.U
Heating cars from 50° to 200°	102
Heating clay „ „ „ 200°	900
Heating water „ „ „ 90°	160
Evaporating water at 90°	4,232
Loss by leakage and radiation, say ...	1,606
	7,000

The weight of air and gases of combustion combined necessary to yield this heat in cooling from 200° to 90° is :—

$$\frac{7{,}000}{\cdot 237 \times 110} = 268 \text{ lbs.}$$

The volume of this at 200° is 4,466 cubic feet.

Now, the 268 lbs. of air and gases have to be raised in temperature by the combustion of the coal from 32° to 200°, which requires $268 \times \cdot 237 \times 168 = 10{,}670$ B.T.U., which is practically the same result as was obtained in the first case.

In this case, however, there is no additional loss in the conversion of the heat as in the case of generating steam. The coal consumption is about 1 lb. or equivalent to 2¼ cwt. per 1,000. The loss by radiation is considerably greater because of the higher temperature employed and the loss from the heater itself by radiation.

The foregoing calculations are sufficiently exact to indicate the efficiency which may be expected from tunnel dryers on the inverse system which are provided with heat by convection (*i.e.*, heated air). They err on the side of moderation when compared with practical performance, and it is necessary here to reiterate the warning previously given of the necessity of accepting with caution the statements given as to the efficiency of different types of dryers. It must be noted, also, that the figures are calculated on an assumption that the bricks contain only 1 lb. each of water of manufacture. The fuel consumption will be increased by at least 25 per cent. if the bricks contain 1½ lbs. each of water to be dried.

It is, perhaps, as well to note here that although the inverse progressive tunnel does not, perhaps, show the fuel efficiency which might be expected from it and is often claimed for it, the labour economy in its use is so great, the independence it gives of weather and seasons is so important, and the space occupied for a given output so reduced, that its adoption is strongly advisable in works where the clay will admit of rapid drying and is not damaged by strong air currents.

This view of the matter will be fully discussed after description of the systems in use.

These systems will not be taken in chronological order, but from the standpoint of method of heat supply, the simple convection method being taken first

CUMMER.

The dryer designed by David Cummer, of Cleveland, Ohio, was, perhaps, one of the earliest inverse tunnel dryers. It was worked originally by using the gases of combustion direct, and later with a tubular coke heater. It is very curious to note that while the Cummer dryer is superseded in America and this country, it is still largely advertised in Germany!

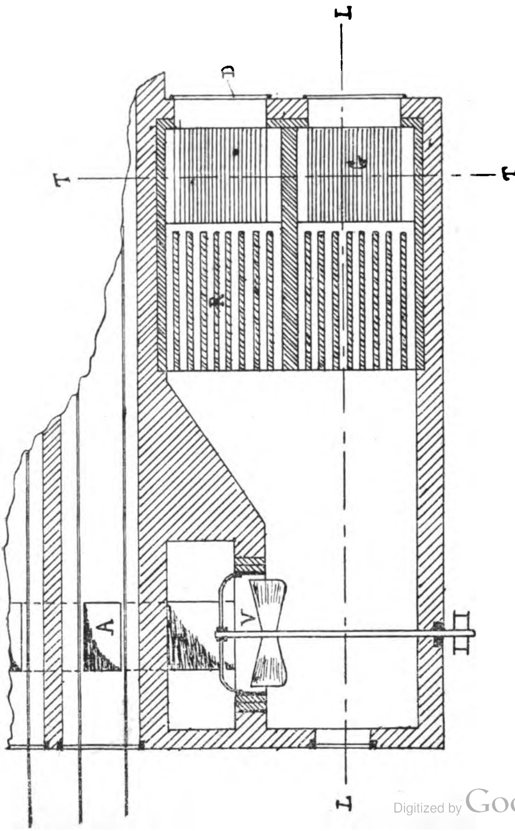


FIG 81.

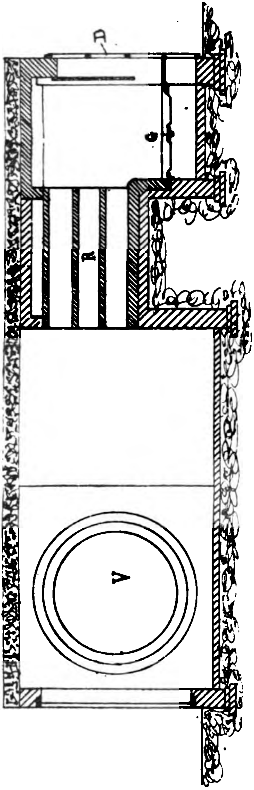


FIG. 82.

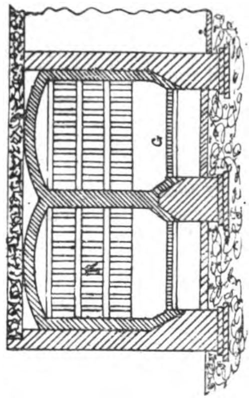


FIG. 83.

BLACKMAN.

The Blackman Ventilating Co. have also installed dryers on both these principles, the heaters for which are illustrated in Figs. 81 to 84.

It is quite unnecessary to illustrate the tunnels themselves, as they in no way differ from the typical form illustrated in Figs. 79 and 80, p. 125.

For the direct use of the diluted gases of combustion, the most approved form of furnace is that shewn in Figs. 81, 82 and 83.

An ample grate surface G is provided for the combustion of coke at a comparatively low temperature. A fan of the ventilating type V creates the required draught, and delivers the hot gases into the service flue A of the tunnels. The furnace front is provided with doors D of large area, formed of wire gauze of close mesh. These create sufficient resistance to the passage of air to ensure the requisite supply to the grate itself.

The air which passes through the wire doors dilutes the gases of combustion, and adjustment is easily obtained by opening them till the required volume of gases is found to be delivered to the tunnels at the proper temperature.

A regenerator R is provided between the grate and the fan for the purpose of equalising the fluctuations caused by varying intensity of combustion. It is built in firebrick, and in practice enables a sufficiently uniform result to be obtained.

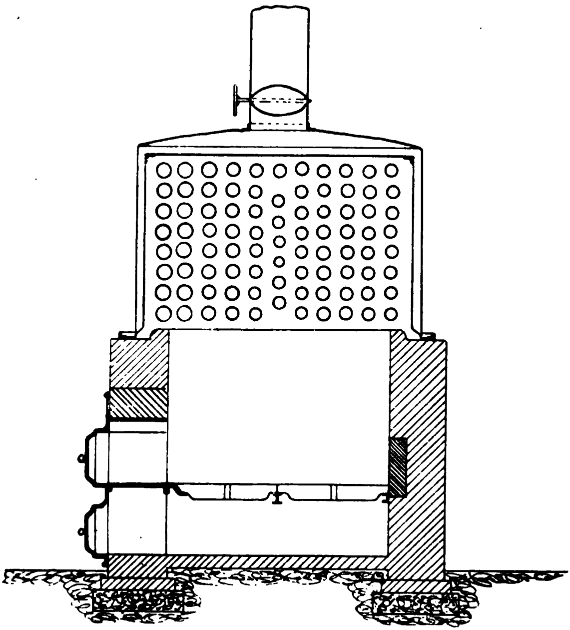


FIG. 84.

Fig. 81 is a plan, and Figs. 82 and 83 longitudinal and transverse sections on the lines L L and T T respectively. This furnace is known by the name of "Slab-Heater." It is employed in other modifications of the Blackman tunnel dryers which will be described later.

The tubular coke heater employed by the Blackman Ventilating Co. for the heating of pure air is shewn in section in Fig. 84.

The products of combustion are passed over a series of wrought-iron tubes, and then issue by the chimney into the open air. Air is drawn through the heater tubes by the fan which delivers it to the service flue of the tunnels.

As remarked before, the products of combustion in this form of furnace leave the chimney at a high temperature, so that there is a considerable waste of heat, and it cannot be considered an efficient arrangement.

Both this and the slab-heater when placed above ground lose heat by radiation, so that it is preferable to construct them when possible in the ground or even beneath the tunnels themselves.

SUTCLIFFE.

The Sutcliffe Ventilating Co. shew a slab-heater sunk below ground level and at one side of the tunnels. The disposition is rather different from the Blackman heater in that the excess air supply for dilution of the combustion gases is passed between the heater and the heater roof, the volume being regulated by a simple counterbalanced register.

STEAM HEATERS.

Steam heaters when used alone are always placed under the tunnels at the warm end. Two types of these are employed the tubular heater and the pipe heater.

The tubular heater is practically a surface condenser, with cold air as the condensing medium.

It is cylindrical or boiler-shaped and from 10 to 12ft. long, with a varying number (from 150 upwards) of 3in. tubes through which the air is blown by the fan.

Exhaust or live steam is admitted at the top and at the end furthest from the fan, and in the under side is a trap for

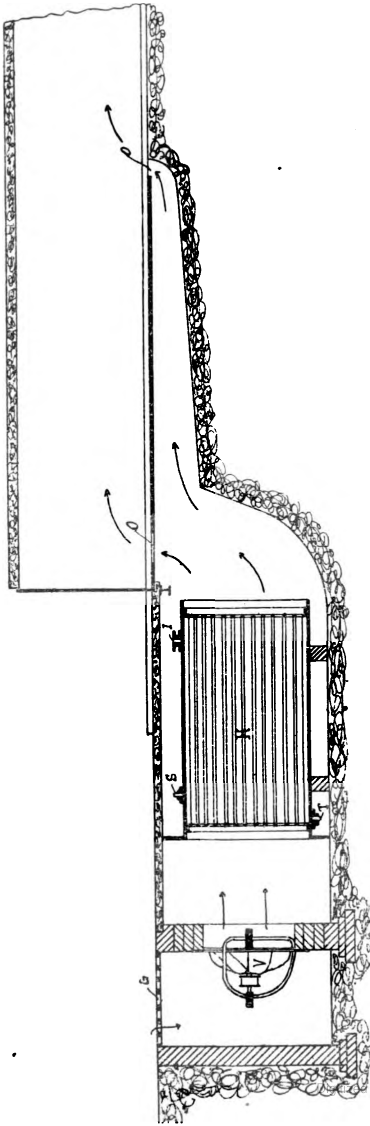


FIG. 85.

draining away the condensed water. A safety valve also is usually attached, set to blow off at about 60lbs. pressure.

This form of steam heater is adopted by the Blackman and the Sutcliffe Companies, and the details of position, &c., as planned by the latter are shewn in longitudinal section in Fig. 85.

In this the heated air is delivered into the tunnels, through two or more openings *O* in an iron-plate floor carried some 20 feet along the hot end of the tunnel.

I is the steam inlet, T the outlet trap, and S the safety valve The fan V draws the air through the grating G and delivers it through the tubes of the heater H.

This form of heater is satisfactory for use with live steam or exhaust steam separately, but is not to be recommended for the combined use of both.

AMERICAN BLOWER CO.

The pipe heater used by the American Blower Co. and others is a more efficient appliance, though more costly to instal. Being constructed in sections placed one behind the other, the first ones may be supplied with exhaust steam which will heat the air to 150° or 160° and the last one or two with live steam in small quantity which will raise the temperature of the air finally to 170° or 180°. Each section is entirely independent with separate steam supply pipe and draining trap.

It consists, as shown in Figs. 86 and 87, of four rows of pipe 1-in. diameter fixed in a hollow base. Each pipe with its connecting elbows forms a complete inverted U, one leg of which is open to the chamber B and the other to the chamber C of the base.

A supply pipe A conducts live or exhaust steam into the chamber B, and the chamber C receives the condensed water which drains away by the pipe D. This draining pipe is fitted with a trap to prevent the escape of uncondensed steam.

Fig. 87 is a plan of the base, and the arrows show the direction in which the air to be heated is passed over the pipes.

Six sections are usually placed one behind another, and the whole are encased in sheet iron. The back is left open to the main duct which supplies the tunnels with heated air, and on

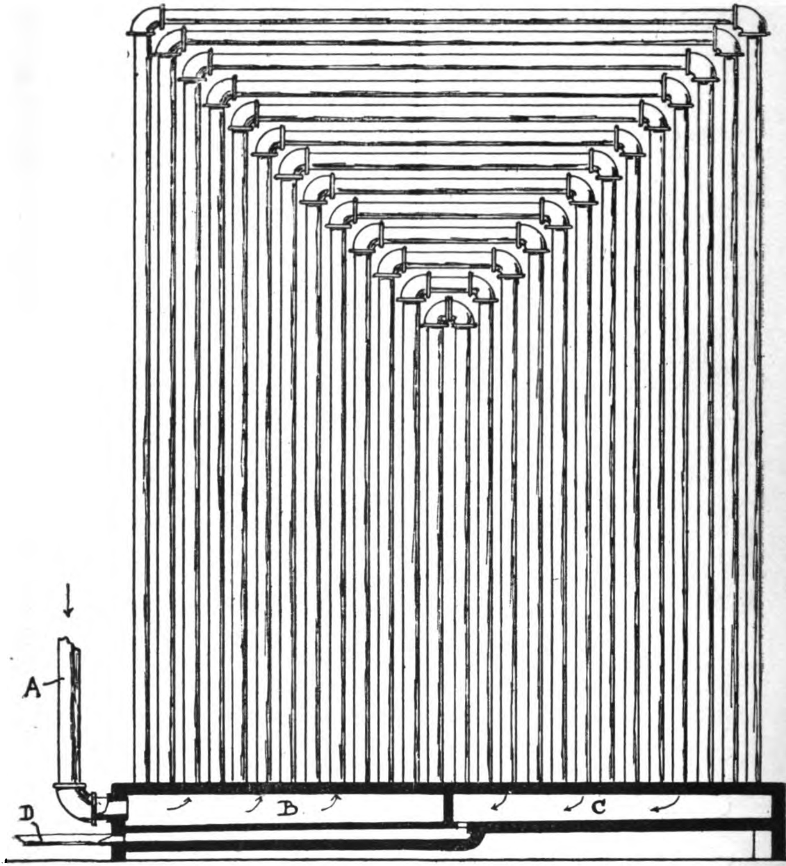


FIG. 86.

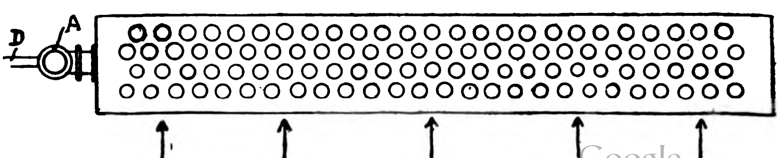


FIG. 87.

the front a casing is provided with a fan placed centrally to deliver cold air over the pipes, as shown in Fig. 88.

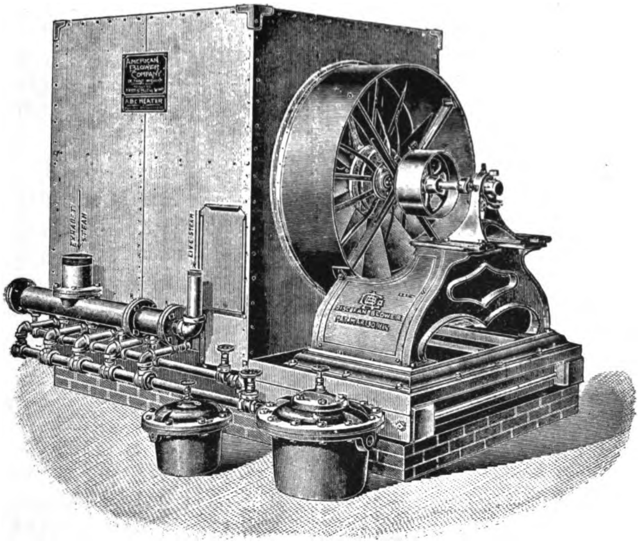


FIG. 88.

A heater of this form is very compact, and provides a very large heating surface. In the size shown in the figures, 5ft. by 5ft. by 6ft. 6ins., the surface is upwards of 1,200 square feet, and may be used to condense 1,800 lbs. of steam per hour. The tubular steam heater on the other hand, 5ft. 6in. in diameter, 12ft. long, with 200 3-in. tubes, contains 1,900 square feet of surface, and will condense about 2,500 lbs. of steam per hour.

With both appliances, of course, the condensed water issues hot from the heater, and should be used for the boiler feed.

In connection with this point a difficulty occurs with steam impregnated with the lubricating oil which is introduced into the engine cylinder by a sight-feed lubricatoı. To meet the difficulty, the American Blower Company have introduced an ingenious oil separator which separates the oil mechanically from

the steam before it is condensed. Filtration of the water after condensation of the steam is not found to be efficacious on account of the extreme fineness of the oil globules and the close mixture, in the nature of an emulsion, which they form with the water.

The American Blower Company instal the tunnels in the typical form without any notable variation, and no attempt is made to adopt any other principle than that of convection for the heat supply.

The Sutcliffe Ventilating Company, as shewn in Fig. 85, fix an iron plate floor for some portion of the length of the tunnel at the hot end. This imparts some amount of heat by radiation to the bricks over it, but it cannot be considered as a serious attempt at the introduction of the principle of radiation.

In their more recent designs, however, the Blackman Ventilating Company have introduced a combination of heating methods of much greater value. In this the sheet iron floor is extended for the whole length of the tunnel and a duct of uniform cross section is provided in which hot products of combustion are circulated. These part with their heat to the sheet iron which radiates it to the goods in the tunnel. The heat so supplied may be produced in a slab-heater of the design shewn in Figs. 81, 82 and 83, or may be obtained from the waste gases of kilns, intermittent or continuous, or it may be obtained by a combination of slab-heater and continuous kiln gases.

At the same time as heat is being provided by radiation through the floor, a certain quantity is also supplied by convection by means of a tubular steam heater. Pure air from outside is heated in this and delivered *into* the tunnel passing amongst the goods to be dried and carrying off the moisture.

A further modification is introduced in the form of a duct over the tunnel separated from it by a ceiling of light corrugated iron. This ceiling is interrupted at intervals by openings leading from the tunnel into the duct and the object of the arrangement is to reduce the volume of air passing over the bricks as it proceeds from the hot to the cold end of the tunnel.

In this way the volume of air required is much less than that indicated by the calculation given at the commencement of this article, because a considerable quantity of the heat required for

drying is supplied by radiation through the floor. Not only so, but it becomes reduced still further in its course among the goods so that the newly introduced wet bricks are not subjected to strong air currents at a time when they are most sensitive, and most liable to cracking.

The calculation of the total amount of heat required to dry bricks given at the commencement of this article still holds good, but the method of supply being different it will be interesting to examine the conditions which now obtain.

It will be specially interesting to do this in connection with the employment of the waste gases from a continuous kiln, a process as yet only in course of development.

The tunnel before quoted will give an output of 34,560 dry bricks per week of six days, or say 100,000 per week for three tunnels.

A continuous Hoffmann kiln of modern type with advance drying or warming, which will give the same output of burned bricks, is found to give about 5,400 cubic feet of gases per minute at about 200° F.

If the draught for the kiln is created by an induced draught or suction fan of the Sturtevant type instead of a chimney, these hot gases may be delivered direct to the tunnels beneath the iron floors.

Each will receive about 1,800 cubic feet per minute which will be reduced in temperature by the radiation through the plates to about 120°.

The heat therefore yielded by them is :—

$$108\text{lbs.} \times {\cdot}237 \times 80° = 2{,}047 \text{ B.T.U.}$$

This is one-third of the total of 6,000 B.T.U. required per minute to dry the bricks. The volume of air required inside the tunnel is correspondingly reduced by one-third and now stands at 3,333 cubic feet per minute at 170°, which exacts the provision of 6,900 B.T.U.

The coal consumption is consequently reduced to 2cwt. per 1,000 bricks dried if live steam be used and to $1\frac{1}{8}$cwt. if exhaust steam be used by day and live steam at night.

The power required to drive the induced draught fan may be neglected, because it is but little, if any, in excess of that

required to supply the additional volume of air if the convection method only be used.

The same induced draught fan may be used to provide the draught for the main boilers, the hot gases from them also will provide a valuable amount of heat as they escape at a temperature of 400° to 500° F. The evaporative power of a boiler is increased also by this means, and at the same time the installation of a fan costs considerably less than a chimney to do the same work.

The construction of this arrangement of tunnels is shewn in Figs. 89 and 90, in longitudinal and transverse section. In Fig. 90, the section shews a construction with two tracks in each tunnel, which avoids the expense of a partition between the alternate tracks in a four or six-track dryer.

The floor F on which the rails are laid is supported on sleeper walls E, 4½ins. thick, which divides the passage C3 beneath it into flues. These may be used to carry either slab heater or kiln gases alone or both. If both are used, the flues can be used, some for one and the others for the other set of gases.

Corrugated iron, 16 or 18 W.G. (not galvanized) is cheaper than sheet iron; it is stronger, gives a greater heating surface, and can be more perfectly jointed. It also affords a better means of attaching the rails without sleepers.

The service flue A distributes the gases from the induced draught fan, which provides the draught for either the kiln or the slab heater. The arrangement of flues for the combined use of both is not here indicated.

The gases pass along the ducts C3, and at B are collected and conveyed to the upcast shaft S, which may be 20 to 30 feet high for carrying the smoke away overhead.

C1 is the tunnel through which the cars loaded with bricks are passed, and it is ceiled with light corrugated iron or boards at G. This ceiling has interruptions at intervals, the position of which is found usually by actual trial. A 2-inch opening, about every four or five feet, leading into the duct C2, is a usual arrangement. R is the air-tight non-conducting roof which may be of concrete, sloped to carry off water.

The steam heater H may be placed as shewn over the tunnels

with fan at V, which delivers the heated pure air into the tunnels at I. It may equally well be placed at the side of the tunnels. The air passes among the bricks carrying off the moisture dried out of them into the duct C2. The volume passing through the tunnel C1 is diminished in its course by the escape of successive portions through the interrupted ceiling, till at the end where the cold wet bricks enter there is practically no current at all, and the bricks are only warmed by heat radiated from the floor.

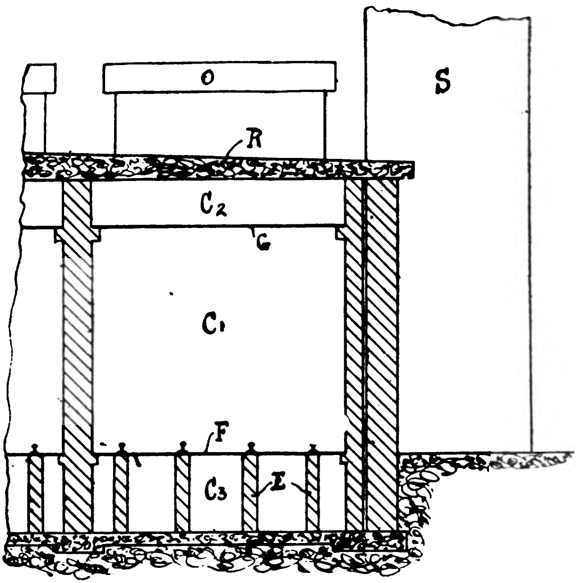


FIG. 90.

The escape of the moisture-laden air from the duct C2 is provided for by the construction of outlets O at intervals in the roof. Three or more may be constructed of suitable size, the first one being placed at about the middle of the tunnels and the others equally spaced along the cooler half of them.

A somewhat similar method of employing pure heated air as the only source of heat is now practised by the Blackman

Ventilating Co. In this case the source of heat is placed at the cool end of the tunnels, a steam heater or tubular coke heater (Fig. 84) being employed.

The hot air is passed first under the floor in the reverse direction to that shewn by the arrows in Fig. 89. Outlets from the duct C3 are made into the tunnels at the end where the dry bricks are taken out, and the air then takes the same course as previously described.

Both these systems are a decided advance on the method of passing the hot air in the simple typical manner from the hot to the cool end of the tunnels; and though that last mentioned is, perhaps, not so rapid in its drying action or so economical in heat consumption, the condensation of moisture on the newly introduced cold wet bricks is entirely prevented.

The use of the waste kiln gases under the floors, however, realises an actual economy, and was first practised in a large installation near Brussels in combination with a Brown's Patent Continuous Kiln of large size.

THE SUN FAN COMPANY.

A modification of the last described system has been introduced by the Sun Fan Co. It has the advantage of placing the source of heat, whether steam or gases of combustion from a furnace, within the under-floor duct. A sheet-iron tube of large cross-sectional area is constructed in the manner shewn in diagram in Figs. 91 and 92. The source of heat is at the hot end of the tunnels, and the air for carrying off the evaporated moisture enters beneath the floor at the cool end at I. In its passage it gathers heat from the iron tube T, which at the same time radiates heat upwards to the floor plates F. These, in their turn, radiate heat to the bricks on the cars.

No ceiling duct is introduced, and consequently there is no means of reducing the air volume as it passes from the hot to the cool end through the bricks.

Openings are provided in the floor plates at intervals as shewn, so that the heated air rises through them underneath the cars and ensures complete drying of the lower tiers of bricks simultaneously with the upper ones. It will be noticed in Fig. 91 that the fan is placed so as to create draught by

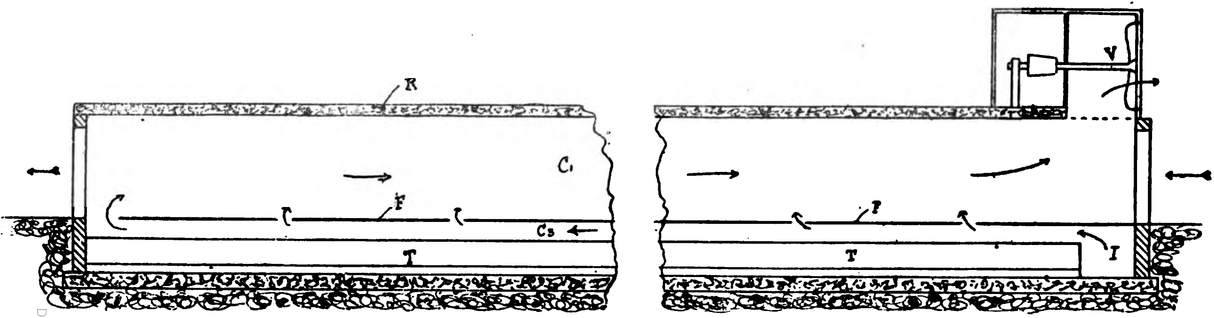


FIG. 91.

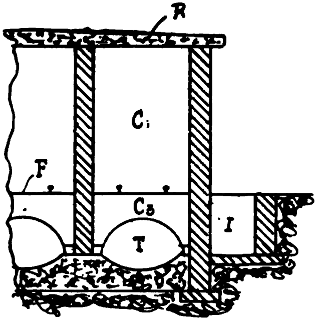


FIG. 92.

suction in contradistinction to the usual method of blowing air into the tunnels. The arguments in favour of either method are fairly balanced, and it is more a question of applicability to the system proposed than of superiority of one over the other.

The use of the iron tube in the under-floor duct allows of the employment of the waste gases of kilns. If this is done a separate steam heater may be used to supplement the heat furnished by warming the air previous to passing it into the space beneath the plates.

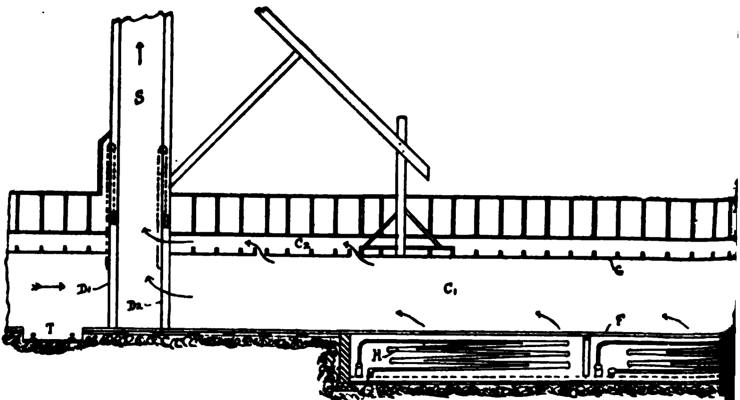
THE WOLFF DRYER COMPANY.

The dryers installed by the Wolff Dryer Company in this country make use of the radiation principle of heat supply to a still greater extent than any of those previously described. The construction of this system is shown in Fig. 93.

According to the output required, as many as 4, 5, or 6 tracks of rails are placed in one chamber without dividing partitions.

The outside walls of this chamber or tunnel are of brick, but with this exception the construction is of wood.

The heating apparatus in this system also is placed below the rail-level, and is in the form of steam radiators, H. The current of air is produced by means of a tall wooden stack S of large sectional area, rectangular in form, and upwards of 80 feet in height. Two means of controlling the air current are provided, the first at the inlet I, which admits air below the


S
C2
C
C1
D1
D2
T
H
F

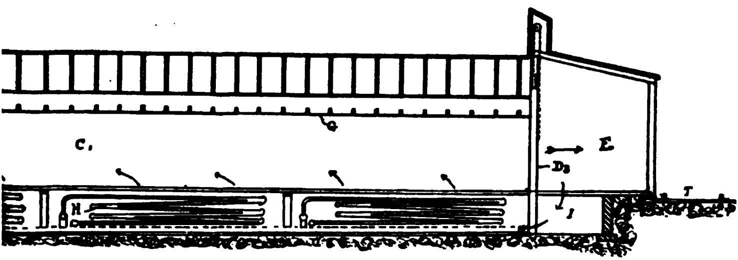


FIG. 93.

radiators, and the other at D2, where sliding doors are placed between the tunnel C1 and the stack.

D, and D3 are entrance and exit doors; R, the roof which is usually a lean-to, and T the transfer tracks for delivery to or collection from each of the tunnel-tracks of the loaded cars.

The floor F, on which the tracks are laid over the radiators, is of wood, latticed, to allow the passage of the heat and air.

A close-boarded ceiling G is constructed, provided at the cool end with one or two openings into the ceiling-duct, C2, for letting some portion of air and moisture away to the shaft. These openings, as well as the main outlet to the shaft, are controllable.

The special feature of the dryer is the form of steam heater employed. This is the outcome of a long experience, and as now installed, is very perfect and efficient. Fig. 94 shows a

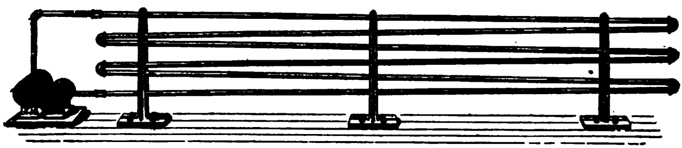


FIG. 94.

portion of one heater indicating the 5-inch service-pipe, 1-inch zig-zag radiator pipe, and the 5-inch collecting pipe. The service and collecting pipes are laid transversely, and the radiating pipes longitudinally in groups under the tracks of rails. They extend, four in number, about three quarters of the length of the tunnel, the remaining quarter at the cool end not being heated, except by the warm, damp air travelling towards the ventilating shaft.

The first radiators at the hot end receive the direct supply of exhaust or live steam into the service pipe. It passes through the radiators to the collecting pipe, some of it becoming condensed and the remainder passing on to the service pipe of the second set of radiators. There the same process is repeated, the amount of the steam supply being so adjusted that the whole is condensed completely, and none escapes from the

fourth set of heaters. Each collecting pipe is properly drained of its condensed water and the hot water is pumped back to the boilers, after filtration, by a very perfect direct acting steam pump.

It will be seen thus that the radiators at the hot end yield a larger quantity of heat than those further along, and graduated temperatures, usually from 115° to 95°F., are obtained within the tunnel. The volume of air employed to carry off the moisture is much less than in the previously described systems, rarely exceeding 2,500 cubic feet per track per minute. The heat is supplied largely by radiation direct from the pipes to the bricks, for it is evident from the calculations previously given that heated air in such volume could not provide a sufficient quantity of heat. The drying process, however, is much slower, being seldom completed in less than 50 hours, and with tender clays occupying sometimes as long as five days.

In the latest installations these latter are subjected, before entering the main dryer, to a warming process in what is termed a "tempering" chamber. This is a separate chamber of about 40 feet in length constructed to receive the goods on the cars before they are passed into the dryer proper.

A single layer of 1 in. piping is placed between the rails of each track and serves to provide enough heat to warm and dry the bricks slightly.

This process may serve to stiffen the bricks for pressing, but is chiefly valuable for the partial prevention of condensation on them when they enter the dryer. In the usual way of proceeding, the condensation on the newly introduced cold bricks is considerable, and even with the use of a tempering room bricks have been found to weigh two ounces more after six hours in the dryer proper than when they left the machine. While the dryer is undoubtedly economical in heat consumption it is capable of much improvement technically.

The chimney stack at the base extends across the full width of the dryer and is contracted somewhat above the roof. As a means of providing the necessary air current, it is sufficiently powerful and obviates the use of mechanically driven fans, but its action is influenced considerably by the weather and there are no means of adjusting the air supply to a *constant* volume.

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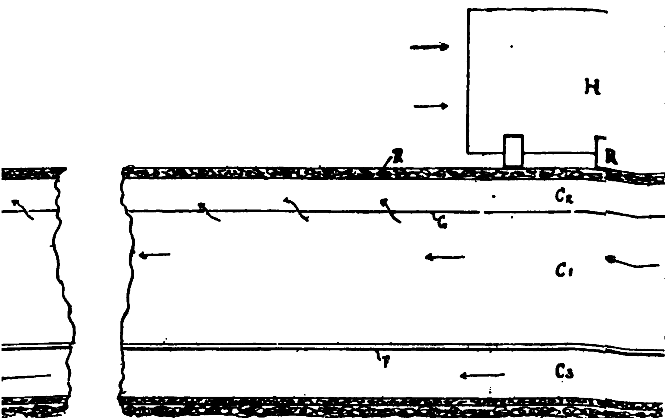

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FIG. 89.

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A comparison of the heat expenditure in this system with hese calculations given on p. 127, stands as follows:—

A dryer giving 4 dried bricks per minute requires, in its usual form, a volume of 3,350 cubic feet of air per minute at 115° which leaves the dryer moist, at 95°, the weight of this is 232 lbs. and the total heat used is:—

	B.T.U.
Heating cars from 50° to 115°	45
Heating clay „ „	390
Heating water „ to 95°	180
Evaporating water at 95°	4,194
Loss by leakage and radiation, say ...	726
Heat carried off by 232lbs. air (95°—32°)...	3,465
	9,000

This calculation shews an economy of about 14 per cent. on those previously given, an economy due entirely to the use of the principle of radiation as contrasted with the use of convection only.

The fuel consumption, if live steam only is employed, in this system works out to 2½ cwt. per thousand bricks dried, and if exhaust steam is used by day and live steam at night, with constant and progressive working, to 1½ cwt. per thousand.

This system does not make use of waste heat from kilns and does not therefore shew the same economy as that described on p. 139 and illustrated Figs. 89 and 90.

THE BUCYRUS DRYER.

The dryer sold by the American Clayworking Machinery Co., under the name of the Bucyrus dryer, has largely superseded the Wolff dryer in the United States.

The most recent form of ventilation adopted in this is shewn in Fig. 95. The heating is by steam on almost exactly the same lines as in the Wolff dryer, except that the steam pipes extend throughout the whole length of the tunnel, and each section of them is under control by means of valves.

As described in the description (p. 101) of the earlier form of this dryer the air is admitted between the ceiling and the roof A and becomes slightly warmed by heat which passes

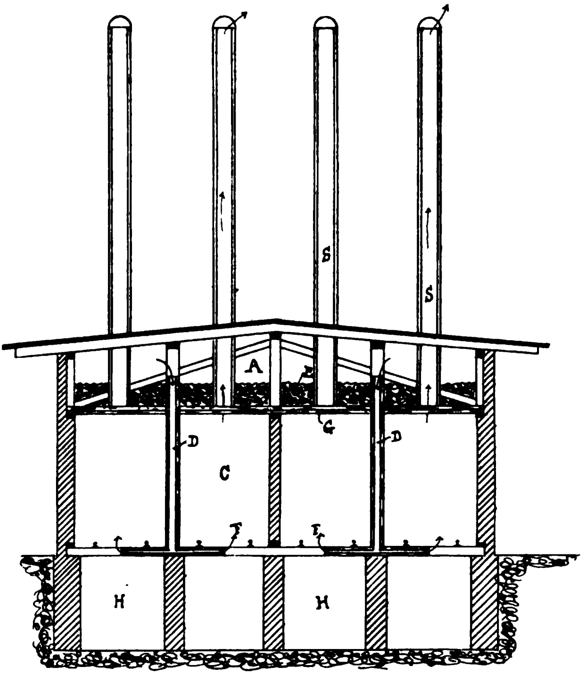


Fig. 95.

through the ceiling G. It then descends a number of rectangular channels D, 10ins. by 2ins. cross-section and enters the tunnels at the floor level between the rails at F. These inlets occur about every 7 or 8 feet in the length of the tunnel, which is usually constructed about 80 feet in length. The outlets of the air are in the centre line of the ceiling of each tunnel, are spaced about 15 feet apart and are about 8 inches square in internal cross-section, and 16 feet high S. Each is controlled independently by a damper so that the amount of ventilation in each section of 15 feet length of tunnel can be adjusted by trial.

The cars carrying the bricks are passed through the tunnels C in the usual way, but it is evident that the ventilation is of a

kind that does not admit of the dryer being classified, strictly speaking, under the present head. The action and efficiency differ but very slightly from that of the intermittent form, and a scientific expression of its practical performance is too complicated to be introduced here.

No dryer is yet erected on this system in England, but the drawbacks to the Wolff dryer are obviated in it, and slow drying can be resorted to without the large amount of condensation which occurs in that form. It is therefore a system which may be specially recommended for drying delicate goods, although in common with all dryers using cars, the installation cost is high if more than three days are necessary for the drying operation.

Back Pressure.

An important consideration in the use of batteries of 1-inch steam piping for dryers is that of the back pressure produced on the engine. In some instances this has been found to be considerable and has led to the abandonment of the use of exhaust steam and the installation of a separate boiler for drying purposes.

In many works these dryers do not condense the whole of the exhaust steam yielded by the engine, and when this is the case the back pressure is undoubtedly high, necessitating a higher boiler pressure to do the requisite work than would otherwise be the case. It has to be considered further that in a week of seven days, during the whole of which steam must usually be provided for drying, the number of engine hours is only 56 out of 168. Only one-third, therefore, of the drying is done by waste steam, the efficiency of which is reduced if back pressure on the engine occurs.

Rappold and Steiger.

The latest development of the inverse tunnel system on the Continent is the invention of Rappold and Steiger, of Zurich.

The design of this system resembles more or less that shewn in Figs. 89 and 90, with certain variations. A special feature is the use of a large portion of the air over and over again, and the condensation of a portion of the moisture

evaporated from the bricks. This is effected by the following disposition of the apparatus, shewn in Figs. 96, 97 and 98.

Fig. 96 is a longitudinal section, Fig. 97 a plan, and Fig. 98 a transverse section.

At A is the furnace which is placed below the tunnels and is surrounded by flues N in which the air returned along flue D is reheated. Part of the air enters the ashpit as indicated by the arrows and supplies the necessary air for combustion.

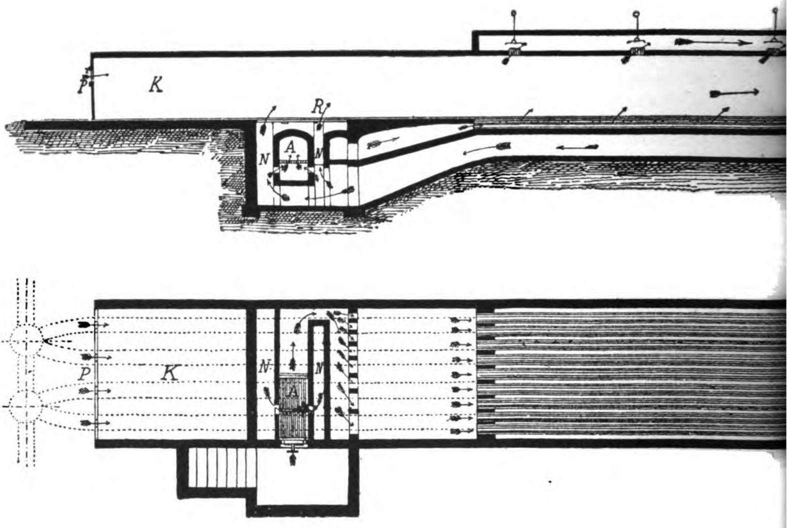
The products of combustion from the furnace A pass along the tubes I, which are laid along the floor of the tunnels B, and the draught is produced by the fan E^1 which discharges them to the open air. In consequence of some of it being used for the furnace combustion the reheated air is reduced in volume when it enters the tunnels at R and an additional quantity enters by the opening P to restore it to its original quantity. This cold air, entering at P, passes over the hot dry bricks in the portion K of the tunnels (called the cooling chamber), cooling them and becoming itself warmed to about 100° F.

In the ceiling are openings, controlled by valves H, which allow of the escape of determined portions of the air into the flue C at different positions in its length. At M the whole of the air, carrying the moisture dried out of the bricks, is drawn downwards by the fans E and delivered into the flue D by which it returns to the heating flues N, and so again into the tunnels at the hot end. In the portion of this flue between the fan E and the drain S, some of the moisture is condensed.

L is the end into which the wet bricks are introduced through the doors O by means of an automatic pushing apparatus G driven by the same countershaft F as the fans.

The length of the tunnels is 140 to 160 feet and the speed of drying is regulated by the volume of air and the heat supplied by the furnace.

The regulation of the drying at different stages is obtained by means of the valves H which can be adjusted by experience to suit the class of clay to be dried. The effect of this adjustment of the valves is to control the amount of air passing over the bricks at their different positions in the tunnels. It may for



FIG

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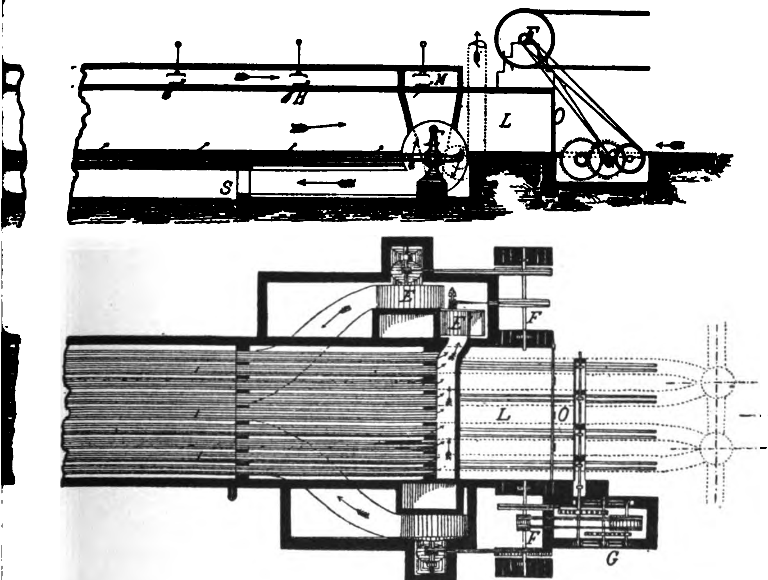


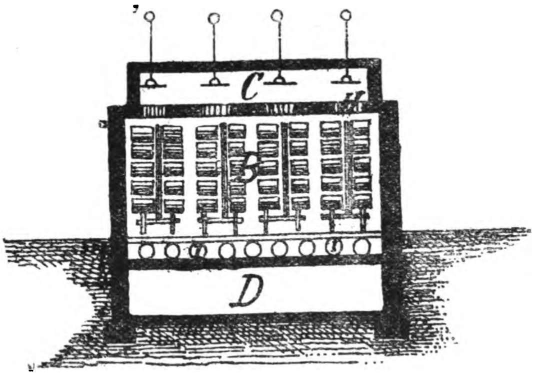


FIG. 98.

delicate clays be reduced to any desired minimum where the bricks enter, in practically the same way as already described in connection with the most improved form of the Blackman tunnels.

The waste of heat is reduced to a minimum and is confined to the three factors of (1) radiation from the walls and roof, (2) heat still retained by the goods and cars on leaving the tunnels at P, and (3) the heat carried off by the products of combustion delivered by the fan E^1 into the open air. The furnace A may be replaced by a steam heated coil and waste gases from kilns may be passed through the tubes I. The losses of heat are all much less in amount than in any of the previously described systems, and this one may therefore be considered as more efficient and more scientifically worked out.

The foregoing are all the systems of inverse tunnel dryer at present in use. In America and France some of them are known under different names, and in various works on brick-making are described under names which it is not necessary to mention here.

In the region of un-practical experiment, there are some devices worthy of notice as examples of attempts to obviate the drawbacks of the inverse system.

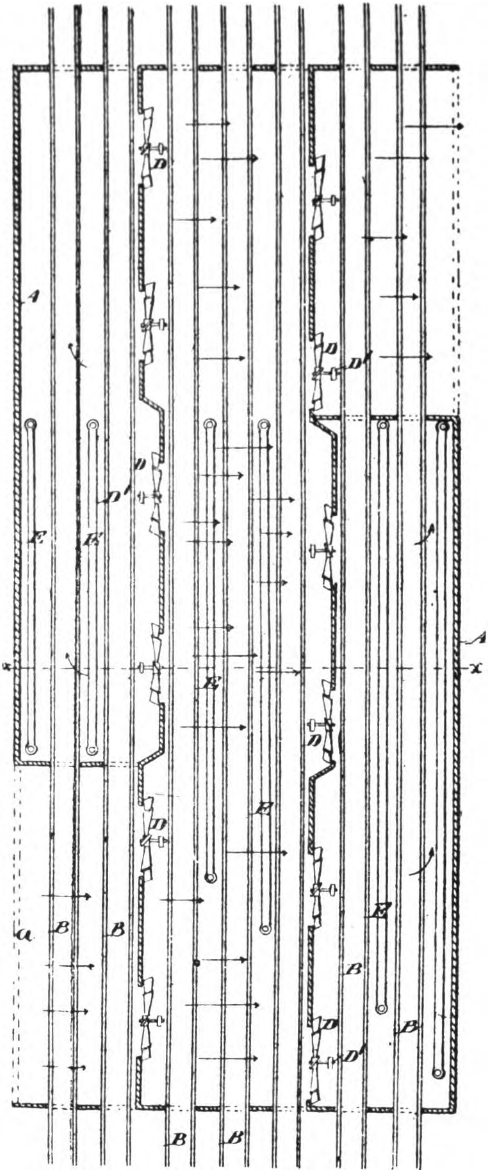


FIG. 99.

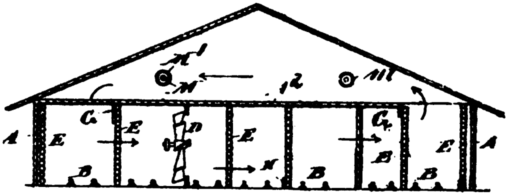


FIG. 100.

PHILLIPS.

In 1891, Phillips, of Woodbridge, in New Jersey, U.S.A., patented a dryer in which the air for drying was made to take a spiral course.

It is of interest to describe this invention minutely, because of many points of resemblance to the Möller and Pfeifer dryer, of which a description will shortly follow.

Fig. 99 is a plan, and Fig. 100 a cross-section of the arrangement on the line *x x*.

Seven tracks of rails are shown, and intermediate to them two rows of fans D, and six rows of heating pipes E.

The air is introduced cold at the side *a*, at the end where the dry bricks are taken out. It traverses the tracks and rises into the space over the tunnel ceiling as indicated by the arrows in Fig. 100. It is then drawn down again into the tunnels on the opposite side, and again traverses the tracks, passing over bricks and heaters successively. After several spiral revolutions it leaves the tunnels at a^1.

The process consists in the introduction of cold air at the dry end, which cools the dry bricks, and recovers the heat contained in them. The temperature is increased by the heaters until these are all passed, when the heat contained in the air is utilized in warming and partly drying the newly-introduced bricks.

The bricks travel in a direction opposite to the general direction of the air movement.

It is evident that radiation plays a considerable part in the operation of this dryer, and the whole invention is of very efficient design.

The drawback to its adoption is the large number of fans employed. These are costly to install, with all the necessary transmission shafting and belting, and absorb a considerable amount of power.

Beyond the description in the Patent Office records, no information is to hand as to actual performance in practice of this dryer.

BRUCKMANN.

In 1893, Bruckmann, of Lagerdorf, in Germany, patented an arrangement in which a "tempering chamber" was used to prevent condensation of moisture on bricks newly made. To this end the tunnel was divided into two lengths by a partition introduced through the roof, which could be raised to allow the passage of the cars. The hot air passed into the hot end was withdrawn at this damper, and a fresh supply of slightly warm air was passed into the cool part of the tunnel to perform the earlier stages of the drying. The second supply of air contained very little moisture, and condensation was thus prevented.

The drawback to this device is that the hot air for drying is passed out of the tunnel at a temperature involving much loss of heat.

HOWL.

In 1897, Howl, of Tipton, devised a means of applying heat to the cars themselves, so that the bricks were dried by contact or conduction. The cars are designed with hollow uprights and frames, and hollow iron pallets communicating with the uprights. Each car has also a water-tight connection with the ones behind and in front of it, so that a continuous stream of hot water or steam through a series of cars coupled together provides the heat necessary for drying.

CHAPTER VII.

III. b. *Dryers ventilated in the same direction as that in which the goods move.*

The direct system of ventilation in progressive tunnel dryers, though tried as long ago as 1884, has only become a practical success within the last three or four years. The principle of its

action consists in the general movement of the air, which carries off the moisture, in the same direction as that of the goods themselves. In other words the air for drying enters the tunnels cold at the cold end, becomes heated in its progress through them, at the same time taking up more and more moisture from the bricks, and leaves them hot at the hot end, where the goods issue hot and dry.

The essential advantage of this method consists in the physical fact already explained (pp. 3 and 41) that the same weight of air can carry more and more moisture as its temperature is raised. The figures there given demonstrate that at 42° F, one pound of air can carry ·089 oz. of moisture, at 82° ·38 oz., at 132° 1·88 oz., and at 182° 11·4 oz.

It follows from this that if the air in such a system leaves the tunnel at say 162°, the weight necessary to carry one pound of water, if it is saturated, is only 3·1 lbs. or 48½ cubic feet, as compared with 50½ lbs. or 689 cubic feet in a dryer on the inverse system working between 170° and 82°.

As a matter of fact the carrying power of the air increases so rapidly with the rise in temperature that in practice it is not usual to attempt to make it issue saturated at the hot end. If this were done the drying would be extremely slow at first and very rapid at the end of the operation. If the rise in temperature were regular in such a case, the air entering at 42° saturated and rising regularly to 160° in a tunnel, the drying would be represented by the curve given in Fig. 101. In this the base line represents the number of hours of the drying process and the vertical lines indicate the amount of water evaporated out of a brick in pounds. Such a diagram is a practical impossibility, and that given in Fig. 102 is more nearly what is actually aimed at in practice in this, as well as in the inverse, form of tunnel dryer. The corresponding form of curve for slow drying in a uniformly heated and ventilated chamber is given by the diagram Fig. 103, which represents proportionally the effect in the case quoted on page 14. In the first two, supposing the brick to be dried in 24 hours, the distance from one vertical line to the next represents a space of time of four hours, in the third it represents 24 hours because the time of complete drying was six days.

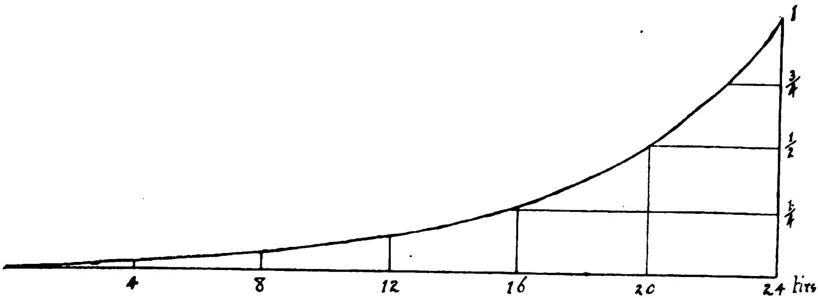


FIG. 101.

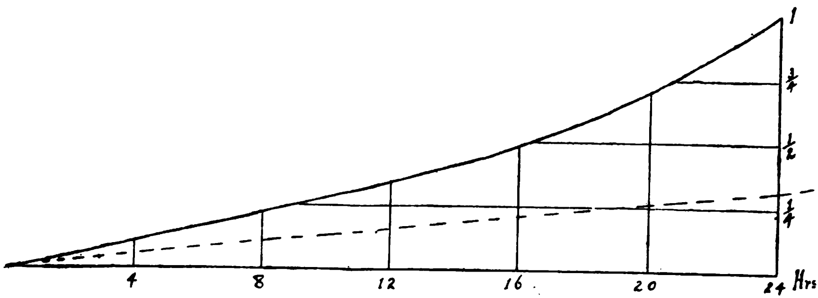


FIG. 102.

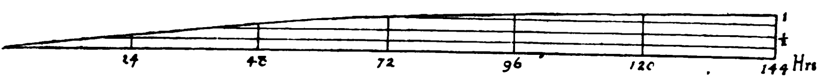


FIG. 103.

The dotted line on Fig. 102 is the drying effected in the third case in the first 24 hours and is therefore on the same scale. Now in the case of Fig. 102 if the drying is on the direct system the weight of air per lb. of water evaporated, if kept constant, is 8½ lbs., so that to dry 4 bricks per minute it would be 34 lbs. or 533 cubic feet per minute at 162° F. This is strikingly less than that required in the inverse system as shewn on page 127

being only about one ninth part in amount. This quantity of ventilation too is not affected by the considerations of heat supply, because the heat must be supplied in some manner independent of the ventilation.

The heat calculation now becomes the following :—

	B.T.U.
Heating cars from 50° to 162°	77
Heating clay	672
Heating water	448
Evaporating water at 162°	4,032
Loss by leakage and radiation, say	709
Heat carried off by 34 lbs. air (162° to 32°) ...	1,062
	7,000

This shows a large reduction on the amount (10,350 B.T.U.) required for a similar performance in the inverse tunnel.

A further actual economy of heat, however, is possible with this system, for the air passing at 162° from the hot end of the tunnel may be made to yield up a large portion of its heat again in warming the cool end. Not only so, but some of the moisture evaporated from the bricks may be condensed, yielding up its latent heat in large amount. This is actually done in the Möller & Pfeifer tunnel, to be described further on, and in the above calculated case about 2¼ lbs. out of the 4lbs. evaporated can be re-condensed, the air at the same time being reduced to about 100° F.

The heat recovered in this process is the following :—

	B.T.U.
Cooling of 34 lbs. air 162° to 100°	500
Cooling of 4 lbs. vapour	110
Condensation of 2¼ lbs. at 100°	2,610
	3,220

This amount deducted from the 7,000 B.T.U. necessary by the previous calculation leaves 3,780 B.T.U. to be supplied.

The whole question of efficiency rests now on the manner in which this amount of heat is supplied to the tunnels. Exhaust steam alone will not supply heat at a sufficiently high temperature, and it is usual at the hot end to provide radiators heated by the gases of combustion of a furnace. Between the part of

the tunnels heated in this way and the part heated by the returned hot air and latent heat of condensation, it is usual to place radiators heated by exhaust steam by day and live steam by night. These two sources must supply the 3,780 B.T.U. per minute above calculated. Of this the steam is proportioned to supply about 1,780 B.T.U. and the fuel heater about 2,000 B.T.U.

The actual fuel consumption per 1,000 bricks thus works out to about 1 cwt. per 1,000 bricks dried if exhaust by day and live steam by night are used under the above conditions.

When it is considered further that the most delicate goods may be dried on this system with certainty of success it is evident that it is very efficient in comparison with the inverse system.

The reasons why delicate goods may be dried in this way are obvious. The air which carries off the moisture is very small in volume and is so heavily charged with moisture as to be nearly saturated during the greater portion of the period of drying. In consequence of this the bricks are never subjected to surface drying or to strong air currents.

It is not generally recognised among drying engineers that a really delicate brick, most difficult to dry, has two critical periods, and not one only as in the majority of clays.

The first is when it is first made and the second when it is what is technically called black hard, that is, when shrinkage is complete. A tender sandy clay at this stage will crack if subjected to a draught of dry air or too much radiated heat. It is this phenomenon which is most difficult to avoid in rapid tunnel dryers and which cannot be avoided on the inverse system if the time of drying is sufficiently short to be economical.

By means of the direct system, however, this can be done with success.

Bock.

The earliest form of progressive tunnel dryer, working on the direct system of ventilation, was invented in 1884 by Otto Bock, of Berlin.

The tunnels (Fig. 104) were of the usual typical form, but along the whole length of them beneath the rails were placed steam pipes. At the cool end A at which the cars entered, the

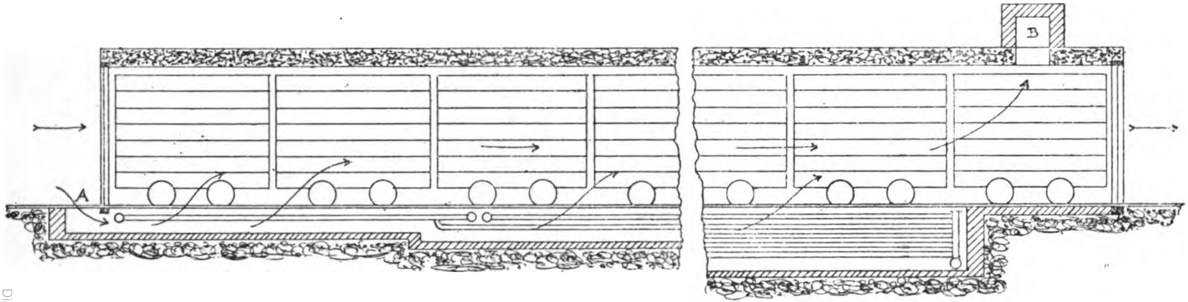


FIG. 104.

radiators consisted of one horizontal row of pipes only. These were, at a certain distance, supplemented by a second row beneath the first and similarly at intervals, until at the hot end some five or six rows were installed. The amount of heat supplied by the radiators was therefore progressively increased from the cool to the hot end of the tunnels. At A the air entered over the pipes and was drawn over the bricks from the cool to the hot end, absorbing more and more moisture, and becoming more and more heated in its passage, till it left the tunnels by the way of the chimney or fan connected with the outlet flue B.

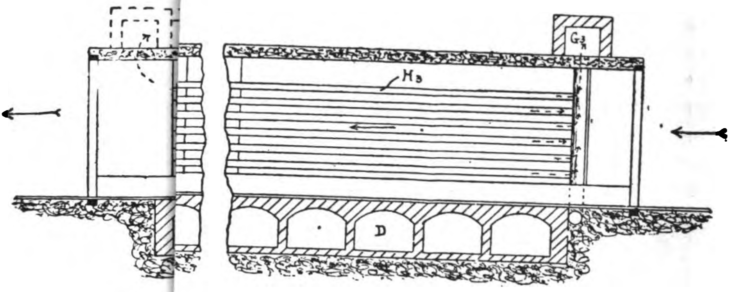
The bricks entered the tunnels at the cool end and were withdrawn from them in the usual way at the hot end, hot and dry.

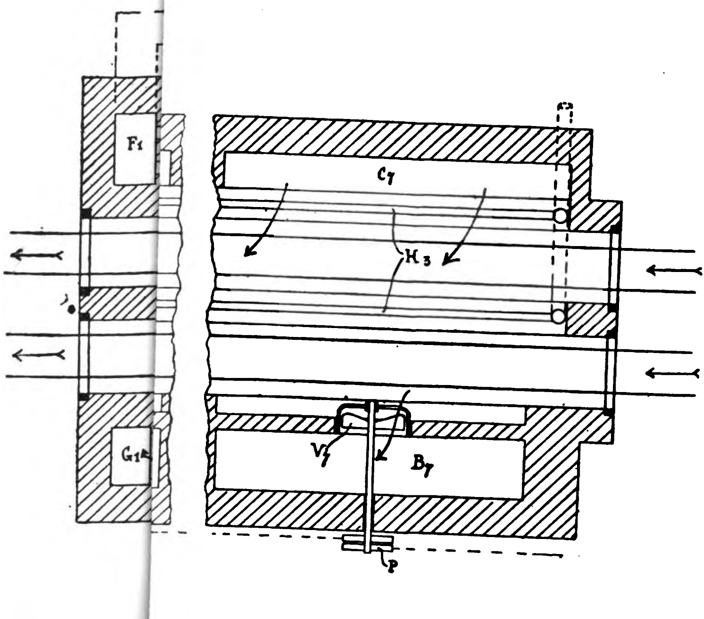
This simple form of dryer did not prove satisfactory, though it possesses apparently all the elements of successful working. The reason adduced for its abandonment appears to be, that moist warm air accumulated along the upper part of the tunnels, so that the upper bricks were still moist when those lower on the cars were completely dried. A more energetic ventilation was considered necessary to obviate this difficulty and could not be satisfactorily applied in this system of working.

Probably the chief defects of the original form of the invention lay in the difficulty of keeping a large number of steam pipes from leaking, and in the want of sufficient experiment to discover the true causes of inefficiency and unsatisfactory working.

The former difficulty is obviated by the more recently perfected form of piping in batteries of 1 inch diameter pipe, such as are used in the Wolff and the Bucyrus dryers. The invention of the writer, described later, is the outcome of much experiment, and demonstrates the fact that the original idea was in reality sound in principle.

The Wolff dryer also has been successfully modified to this system, by a simple reversal of the draught, in at least one case where the bricks were of such a delicate nature that they would not admit of the large amount of condensation on them at the cool end which occurred when the dryer was worked inversely.


G3
H3
D


F1
C7
H3
G1
V7
B7
P

Möller and Pfeifer.

To overcome the difficulties encountered by Bock, Möller and Pfeifer, of Berlin, in 1896, devised the dryer known by their name and now in extensive use on the Continent.

In this the small volume of air for drying is still adhered to, but it is given a rapid circulatory movement within the tunnels themselves by means of a series of fans placed along one side of them.

A spiral or corkscrew movement is thus given to the air, almost precisely the same as in the Phillips dryer, described on p. 153. The air is repeatedly passed over the goods and over the heaters, which are placed between and beside the tracks. The form of construction bears a striking resemblance to that of Phillips, but was doubtless arrived at independently and without knowledge of that invention.

The details of the Möller and Pfeifer dryer are shewn in Figs. 105, 106 and 107. Fig. 105 is a cross-section of a two-track dryer on the line Z Z of Fig. 107. Fig. 106 is a longitudinal section on the line X X of Fig. 105, and Fig. 107 is a sectional plan above the rails, on the line Y Y of Fig. 105.

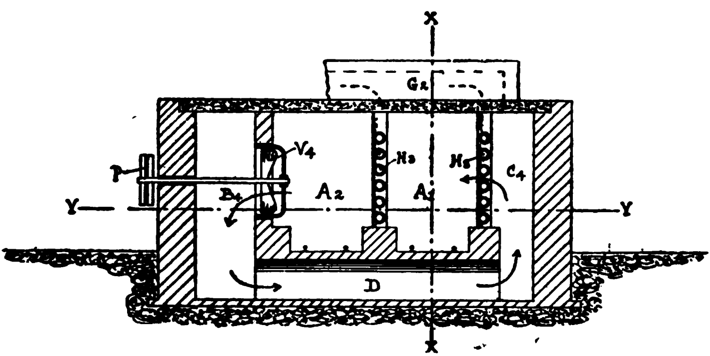


Fig. 105.

The heaters are shown diagrammatically for simplicity. They are usually all in the form of gilled tubes, for giving the largest possible heating surface. F

Three forms of heater are employed, the first H^1, on the outer side only, being supplied with the products of combustion, at a high temperature, of the furnace F. After giving up a large proportion of their heat these products of combustion escape by the flues F^1 and F^2 to the chimney S.

The second sets of heaters H^2 are installed by the side of each track and are supplied with live or exhaust steam. .The third sets H^3, occupying a considerable length of the tunnels, are also installed beside each track and receive the hot moisture-carrying air, which has done duty in evaporating the water from the goods dried. This air is drawn from the hot end of the tunnels through the flues G^1 and G^2, passes through the tubes of the heaters H^3 and thence through the flue G^3 to a small fan, not shewn in the drawing. The direction taken by the air after leaving the tunnels is indicated by the dotted arrows in the figures. This small fan gives the longitudinal motion to the air as it passes among the bricks, while at the same time a rotatory or spiral movement, more or less rapid, is given to it by the fans V^1 to V^7 placed along the side of the dryer. Each of these fans draws the air, as indicated by the arrows, transversely over the goods and delivers it, by way of the chambers B^1 to B^7, through the underground flues D to the chambers C^1 to C^7 on the opposite side of the dryer.

In this way the air is repeatedly passed over the heaters, absorbing heat, and over the bricks, giving up to them the heat necessary to warm them and evaporate the water dried out of them. The air enters by openings in the doors of the tunnels at the cool end.

The fans are actuated from a counter-shaft at the cool end, by means of belts indicated by dotted lines and two pulleys P on each fan shaft. The number of fans is determined according to the length of the tunnels and the nature of the clay to be dried.

Adjustment of the speed of rotation of each fan is obtained easily, according to requirements, by varying the sizes of these pulleys. This adjustment is made once for all to suit the peculiarities of the kind of clay to be dried, and is the means of securing certainty of action without damage to goods.

To make the action of the drying air quite clear, the whole course of its movement may be re-stated as follows :—

Cold air enters by the doors at the cool end and by means of all the fans is passed spirally along the tunnels to the hot end. It leaves them by the flue G^1, and by way of G^2 enters the heaters H^3. Here it is cooled to a comparatively low temperature and a large proportion of the moisture dried out of the bricks is condensed and yields up its latent heat. The air then is discharged finally by the single fan connected with the flue G^3.

The cars carrying the bricks to be dried are introduced at the cool end by a mechanically driven pushing apparatus, which at the same time discharges, at the hot end, the cars carrying the hot dry bricks.

The tunnels are constructed from 100 to 200 feet in length according to requirements, and if it is required to deprive the goods of their hygroscopic water as well as the water of manufacture, a temperature as high as 250° F. is reached at the hot end. This is not advisable in ordinary cases, because a brick so dried will, in a very few hours, re-absorb hygroscopic water from the atmosphere. This would occur before most of the bricks could be set in kiln and put under fire for burning.

Möller & Pfeifer claim to be able to dry any clay, no matter how delicate, in 24 hours, and many clays in considerably less, and the consensus of opinion is to the effect that they perform what they promise.

It will be observed that the supply of heat for drying is effected by a combination of the principles of radiation and convection, and that the extent to which either or both these principles is employed is under complete control.

There is no doubt that the dryer is the most scientifically designed and the most efficient on the market at the present time, but a glance at the drawings is sufficient to convince one that in comparison with some of the dryers previously described it is very costly to instal.

The power absorbed by the numerous fans, also, is considerable, counterbalancing to some extent the fuel efficiency of the

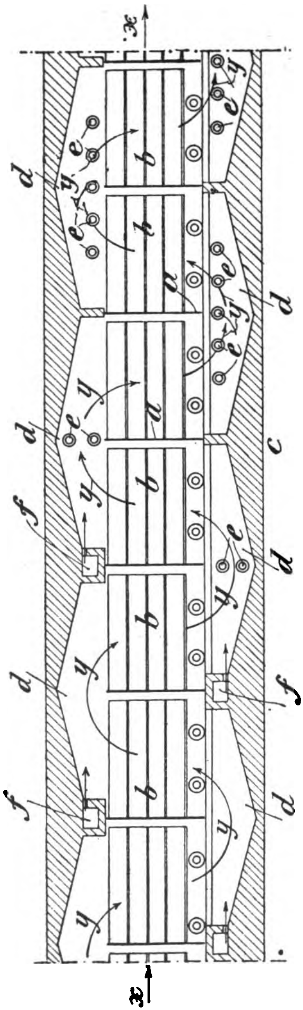


FIG. 108.

dryer. It is, therefore, doubtful whether it will find a ready acceptance in England, and when it is installed then only for drying tender clays, which cannot be dried in the tunnels worked on the inverse system.

One dryer is constructed on this principle in England, on the works of the Farnley Iron Co.

Bourry.

The well-known brickworks engineer, C. E. Bourry, of Paris, has patented, in 1899, a simplication of this dryer, designed to do away with the employment of such a number of fans along the side of the tunnels. Fig. 108 shews the design in longitudinal section. The floor and roof of the tunnels are constructed in zigzags as shown, so that the tunnels are zigzag in form but of uniform section. Each car *b* is furnished with a baffle *a* which compels the air for drying to take a serpentine course as indicated by the arrows.

At the cool end, air is introduced in small volume by way of the flues *f*, and in its subsequent course passes successively over radiators *e* of gilled tubes, which provide the heat for drying in increasing quantity as it passes towards the hot end.

The hot moist air when it leaves the tunnels may be used as the source of heat for the first of these sets of heaters, and steam or hot gases from a furnace may be supplied to others. The zigzags may be formed in the side walls instead of the roof and floor if desired.

No information is forthcoming as to the success of this invention in practice, but it is evidently simpler and less costly than the Möller & Pfeifer dryer.

Brown's Dryer.

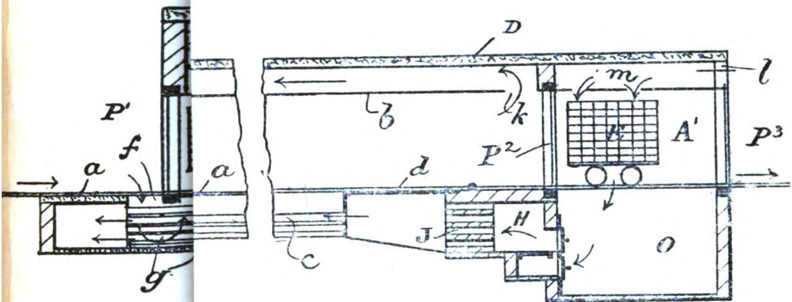
The author has experimented at considerable length with a view to designing a simplification of the directly ventilated tunnel dryer, and has met with good practical success in the disposition of heating and ventilating arrangements shewn in Figs. 109 to 112.

This dryer was patented at the latter end of 1900, by Brown's Patent Kiln, Ltd., and possesses several features in which it differs from those previously described. The first of these is

the means of heating the air for drying before its enters the tunnels. The second, the use, apart from the preliminary warming of the air, of radiation only for the heat supply, such radiation taking place from below and above the cars. The third, the construction of a distinct cooling chamber at the hot end of the tunnels, where the hot dried bricks give up their heat to the air used for combustion in heating furnaces. The fourth the use of the waste gases of continuous kilns as a source of part of the heat, in which case the hot air used for drying after leaving the tunnels is conveyed direct to the heating furnaces for the purpose of combustion. Coke or any inferior fuel is used as the chief source of heat supplemented by steam or waste kiln gases or both.

The figures show a dryer using the two former sources of heat supply, Fig. 109 being a longitudinal section, Fig. 110 a plan, and Figs. 111 and 112 cross sections on the lines *tt* and *vv* respectively of Fig. 110. Below the tracks of rails *a*, on which run the cars E, are placed the furnace and steam heaters. The gases of combustion from the furnace H pass through a regenerator J and then through a series of tubular radiators *c*, which are separated by chambers G covered with sheet iron *d*, to facilitate sweeping and to obviate the effects of expansion. At the cool end these gases finally reach a tubular air heater K in which the air for drying receives its preliminary warming, and the gases themselves yield up all their available heat. They become reduced to a low temperature and are then delivered to the upcast shaft N by the fan L. The supplementary heating by steam (live or exhaust) is provided for by tubes *e*, one inch in diameter.

The circuit of the air for drying is as follows:—It enters at *f* over the tubes of the preliminary heater, and passes in the zigzag direction indicated by the arrows, entering the tunnels moderately warmed at *h*. It then traverses the entire length of the tunnels in the same direction as the cars, becoming warmed by and taking up more and more moisture from the bricks. It flows in a gentle stream, and by reason of the overhead radiation does not require diverting by baffles or keeping in spiral movement by side fans. There is consequently an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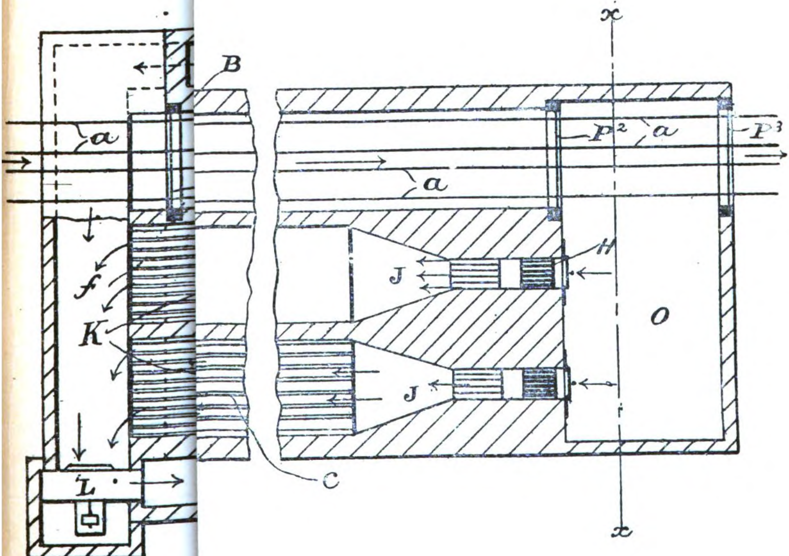
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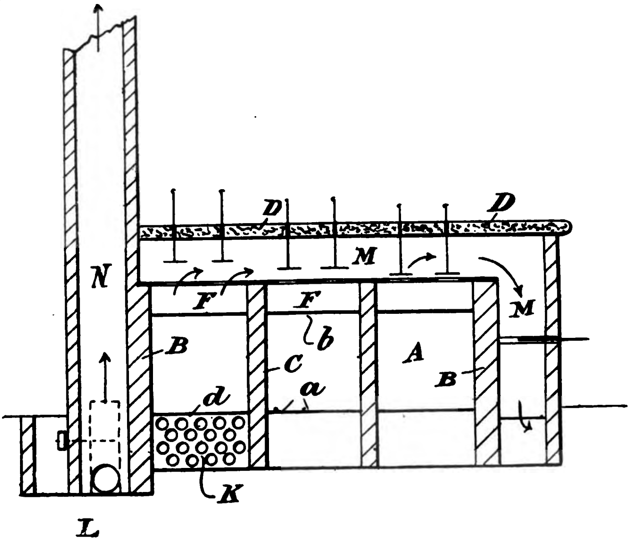

FIG. 111.

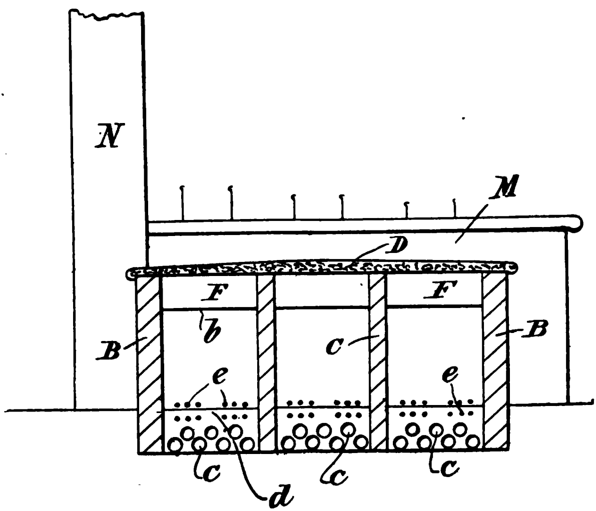

FIG 112.

entire absence of surface drying and its attendant warping, and cracking of the goods. Below the roof D a ceiling flue F is formed either by tubes or, as here shown, by a sheet-iron ceiling *b*. Into this flue the hot air now enters at *k*, travelling in the reverse direction, to the collecting flue M, by which it reaches the fan L. The heat from the hot air radiates downwards through the ceiling.

The air necessary for combustion of the fuel of the furnace enters the cooling chamber at *l* and passes over the hot cooling bricks from the openings *m*, picking up the heat given up by the dried bricks in cooling. The necessary suction of the air and furnace circuits is created by one fan L placed at the cool end. Some amount of condensation of the moisture dried out of the bricks occurs in the ceiling flue F. If kiln gases are used, the hot air on reaching the hot end of the tunnels is supplied to the furnaces for the combustion of the fuel. The kiln gases are blown along the ceiling flue F, which is then separated from the tunnel, providing heat to be radiated from above. The fan L then also induces at the same time the circuits of the furnace gases and the drying air. Steam heating may be substituted entirely for furnace heating, though not with greater economy.

The heat distribution and efficiency are as follows:—Taking as before the heat required to dry four bricks per minute, each containing 1 lb. of water to be evaporated, and assuming the bricks to be dried in two days.

	B.T.U.
Heating cars from 50° to 162°	77
Heating clay " "	672
Heating water " "	448
Evaporating water at 162°	4,032
Loss by radiation, etc., say	771
	6,000

The combined weight of air for drying and furnace gases is about 60 lbs., and as these are rejected by the fan at about 100° F. the loss of heat by them is 967 B.T.U., which added to the above makes a total of 6,967 B.T.U. required. Of this amount the cooling of the cars and bricks in the cooling chamber provides about 667 B.T.U. When kiln gases

are used they supply 1,800 B.T.U. The exhaust steam provides 1,200 B.T.U., leaving 3,300 to be provided by the combustion of fuel. This is equivalent to about 82 lbs. of coke per 1,000 bricks dried, and the corresponding consumption if the kiln gases are not used is $1\frac{1}{8}$ cwt. per 1,000.

The power for creating the draught of the kiln is equivalent to a consumption of about 20 lbs. of coal per 1,000 bricks, so that a distinct economy is realised in this method apart from the other advantages in the burning of the kiln, due to the use of mechanical draught.

The power required to create the draught for the tunnel furnaces and air circulation is very small, not exceeding 2 B.H.P. for a four-track tunnel yielding 15,000 dry bricks daily.

CHAPTER VIII.

CARS.

In connection with tunnel dryers the most costly part of the installations is the cars used for the carriage of the bricks in their passage in progressive manner through the tunnels.

The forms in use are various in design and may be usefully described and illustrated at this point.

SINGLE-DECK.

The simplest type is the single-deck car, Fig. 113. It consists of a simple frame on two pairs of wheels. The standard sizes of the frame are 6ft. 8in. long by 2ft. 8in. wide for tunnels 3ft. 6in. wide, and 3ft. 5in. wide for tunnels 4ft. wide.

Two methods of loading these cars may be adopted. The simplest, suitable only for bricks made very stiff at the machine, consists in piling the bricks in the manner illustrated in Figs. 115 and 116 on a single wooden deck placed on the car frame. They should be piled 8 bricks high and 7 bricks long, crossed

in the narrow cars by 6 bricks wide and in the wide cars by 8 bricks.

The capacity of the narrow cars so stacked is 336 bricks and of the wide ones 448.

The second method of charging with softer bricks, which will not bear so much weight, is by means of a bottom row of flat pallets transverse to the car, with cradle pallets illustrated in Fig. 36, set on them in the same direction.

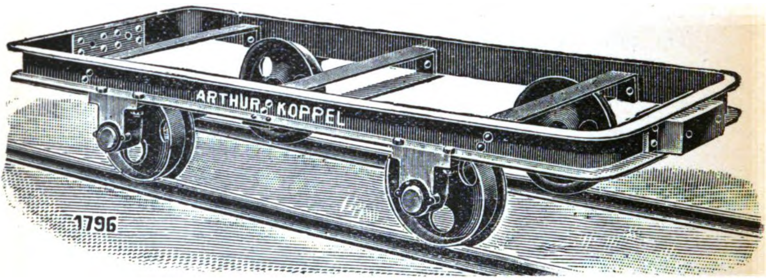

FIG. 113.

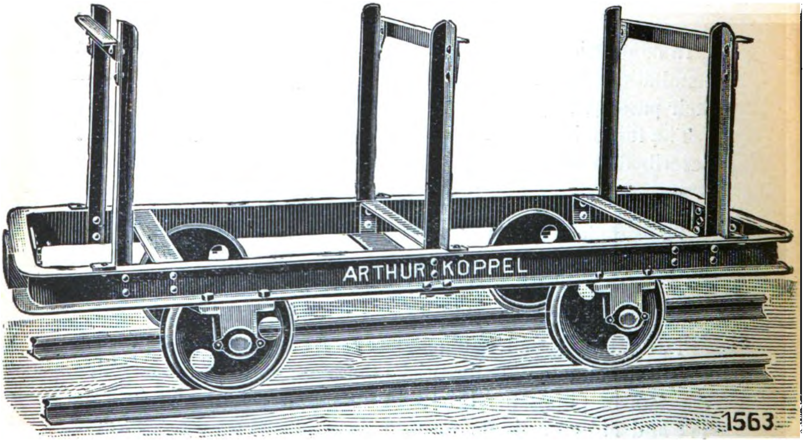

FIG. 114.

On each pallet the bricks are free from weight, and the method may be used for hand-moulded bricks.

The pallets may be stacked from 10 to 12 high for bricks laid flat, each cradle pallet measuring 5¼ inches over all in height. For bricks set on edge they may be stacked 7 to 9 high, each cradle pallet being 6 inches high. The cars will carry 6 pallets in length, and the capacity of the narrow cars is from 294 to 378 bricks, that of the wide ones being from 378 to 486.

The average price of these cars at the present time is £4 5s. each for the narrow, and £4 10s. each for the wide form.

Comparatively few of this type are in use, preference being given to the double-deck cars, Fig. 114, or the rack car, Fig. 118.

DOUBLE-DECK CARS.

The double-deck car is identical in construction and dimensions with the single-deck car, but has the addition of 3 standards placed in such a manner as to carry a second wood deck above 4 tiers of bricks stacked on the frame deck.

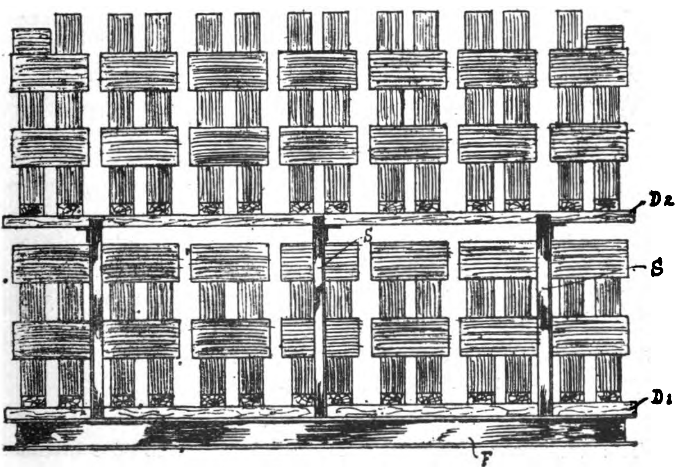

FIG. 115.

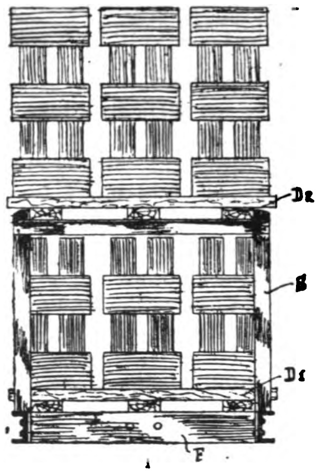

FIG. 116.

On the second deck the bricks may be stacked 4 or 5 high in the manner shewn in side and end elevation in Figs. 115 and 116. In these figures F is the frame, D^1 and D^2 the decks, and S the standards.

The decks for these and the single-deck cars are constructed of wood slats 3ins. wide and 1¼ins. thick, with three strong bracing fillets, 4 by 1½ins., which are placed lengthwise of the cars. It is important to place the bricks of the first tier on each deck lengthwise on the slats, and not bridging across two of them. If placed in this latter manner they will not be able to slip during shrinkage and will crack across the middle.

The narrow type of car so loaded will carry from 336 to 378 bricks, and the wide type from 448 to 504. The price at the present time of these cars is about £5 7s. 6d. each for the narrow and £5 15s. for the wide type.

FINGER CARS.

The finger car shewn in Fig. 117, is intended to take bricks on pallets direct from the wire-cutting table. The cars, standing against the machine on a turntable with one end presented

towards the cutting-table, may be loaded direct by a couple of lads, being turned round when one end is filled.

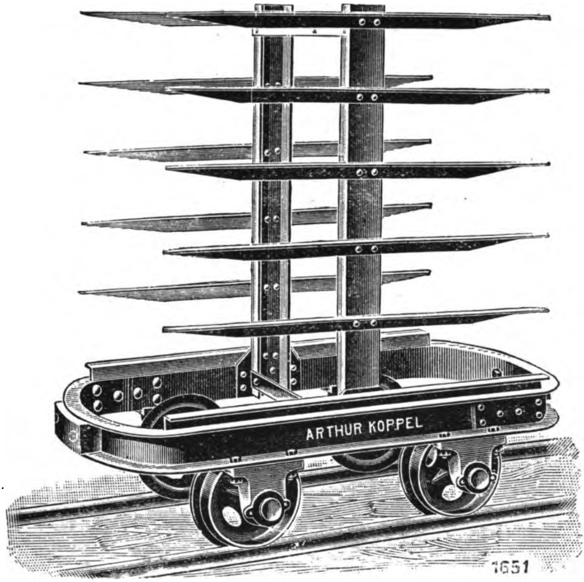

FIG. 117.

This procedure is very simple and could not be improved on if an efficient mechanical device were introduced to separate the bricks from one another by a distance of one inch before the pallets are put on the cars. Such a device has apparently baffled the machine makers up to the present time, and the finger car is not therefore so pronounced a success as it would be but for this difficulty.

The car shewn is 4ft. 9in. long over all and 2ft. 5in. wide. The angle iron fingers are six high and will carry 24 pallets with 240 bricks.

A larger car is also made to carry 6 pallets in length and 7 high, or 420 bricks.

The cost of them respectively is about £5 5s. and £7 5s. each.

Rack Cars.

Rack cars are made in several forms, shewn in Figs. 118, 119, and 120.

The typical form, Fig. 118, is in its standard size 6ft. 8in. long by 2ft. 8in. wide over the frame. It has 3 standards, to which are fixed 1in. angle iron bearers 3ft. long to support the ends of the brick pallets. For bricks on edge these bearers are spaced 7in. apart and 7 high on a car. The pallets are placed 3 wide, each carrying 8 to 10 bricks. The capacity is thus from 336 to 420 bricks.

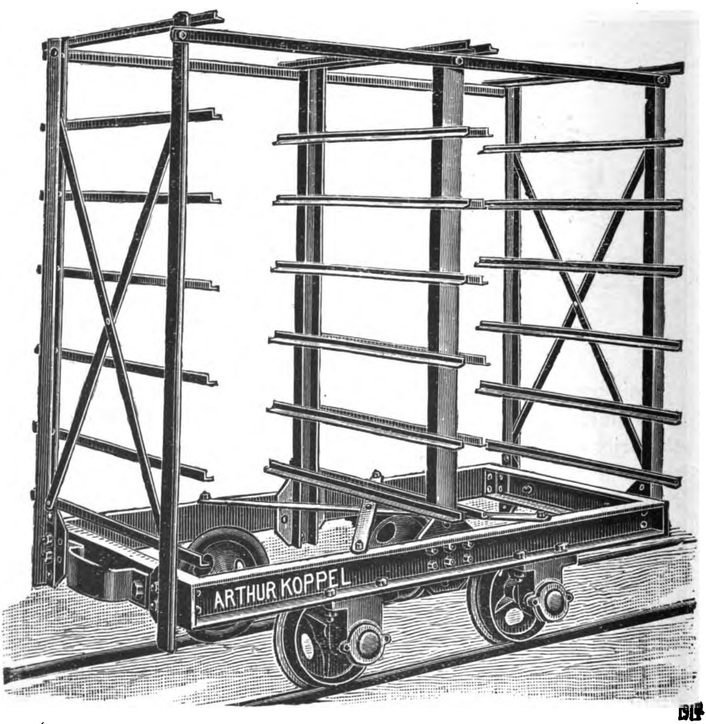

Fig. 118.

For bricks flat the bearers are spaced 4in. to 5in. apart and 12 high on a car. Each pallet will carry 6 bricks, and the car capacity is therefore 432. Fig. 119 shews this latter type with two additional standards, making five in all. It is constructed to take the bricks from a moulding machine such as the "Norris," which moulds three bricks at once.

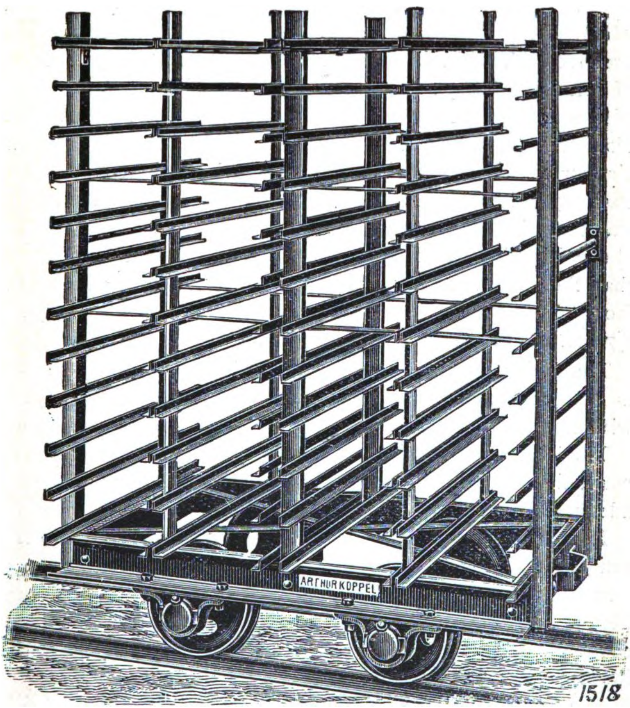

FIG. 119.

The rack car of these American and English types may be loaded from either side. The pallet being placed on the angle iron bearers at the loading side, is loaded with the requisite number of bricks and then pushed along the bearers to the further side. A second pallet then takes its place and is

similarly loaded and pushed up to the first. The third completes the number in the row, and the next tier is proceeded with similarly.

When bricks have to be hand-loaded on to a car, as is nearly always the case, this method of loading is as easy, if not easier, than that adopted on the double-deck car. The first cost, however, of rack cars and pallets is about 50 per cent. higher. There is no doubt that they are, for many reasons, much to be preferred. The bricks on a rack car may be in any condition of softness. They are more exposed on all sides to the action of the air and dry better in the centre part of the car. It is distinctly preferable to expose the brick broadside to the air current than endwise, though at first sight this seems contrary to reason. It is preferable to place a brick in such a way that the moisture dried out of it may rise into a space above it and be carried away by the air current, rather than that the current should come too much in contact with all the faces of the brick. The cost of the rack car is from £6 15s. to £7 10s. each according to the design.

The rack car in use on the Continent is shewn in Fig. 120 and is of much smaller capacity. It has a standard at each end with cross bearers for the pallets placed on them only two wide.

Though a small car is much to be preferred to a large one for convenience of handling, this form cannot be considered of adequate capacity.

It is evident that the greater the capacity per track of a tunnel dryer the cheaper the first cost of the building construction for a given output. While, therefore, a large and heavy type of car is unwieldy for general use, it is not economical either in first cost or labour to adopt one with a lower capacity than 300 bricks.

The Continental car illustrated has a capacity of 160 bricks only. The pallets placed lengthwise are 6 high and 2 wide, and carry each 16 bricks on edge. It is the form adopted in the German dryer of Möller & Pfeifer described above. Its cost is about £4 5s.

The Wolff Dryer Co. adopt cars of larger type throughout than those above described, their double-deck cars being loaded

with as many as 576 bricks. This is necessitated by the slow speed of drying in this system, which, with small capacity cars, would be more expensive to construct in comparison with others.

A Wolff dryer 120ft. long contains 15 cars per track, or 8,640 bricks.

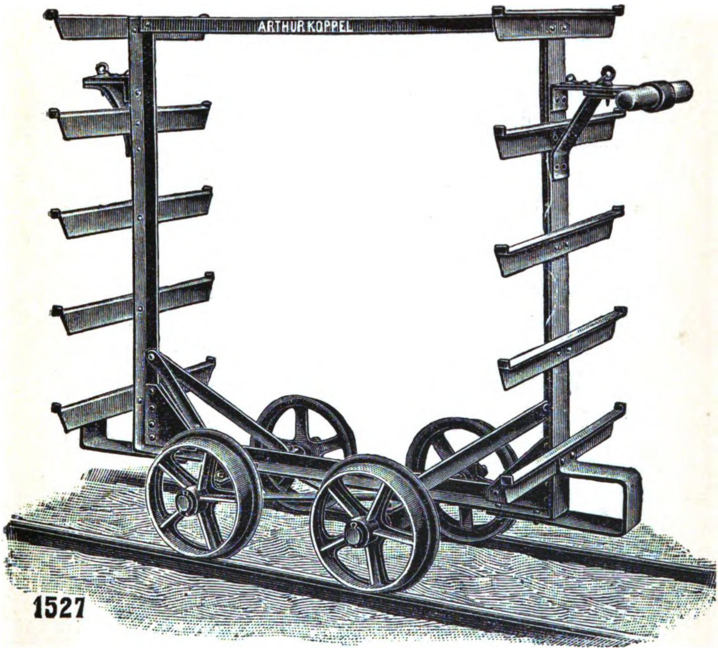

FIG. 120.

The narrow type of double-deck car above described would number 16 in a similar length, carrying an average of 6,048 bricks.

The rack car of similar dimensions would give an average capacity of 5,376 bricks, set on edge.

The cars of all types should be constructed of steel throughout, riveted rather than bolted together wherever possible.

They should be provided with roller bearings and best cast-steel wheels. This last feature is important, though not usually observed by English makers. Cast-iron wheels on any form of railway car are to be strongly condemned.

The wheel is usually 12 inches in diameter, the wheel base 3ft. 6in. and the rail gauge 2ft.

If a somewhat shorter car than the usual type is adopted, for instance, 5ft. 9in. over all instead of 6ft. 9in., the gauge may be 20 inches and the wheel base 2ft. The car can then be used on a 20-inch gauge line and turntables, and will pass much more easily round curves and over switches. The cars are rather more expensive in total cost in such size, but are much more convenient for general use. They will hold about 300 bricks each, and the tunnels need not be wider than 3ft. or 3ft. 3in. per track.

Transfer Cars.

Two methods are in use for transferring the dryer cars from the tunnel tracks to the main track leading to the kiln.

In England and America the usual method is by means of the transfer car and transfer track. The car is illustrated in Fig. 121.

At each end of the dryer a rail track is laid in a trench transverse to the direction of the tunnel tracks, the difference in level of the tracks being about 7¼ inches.

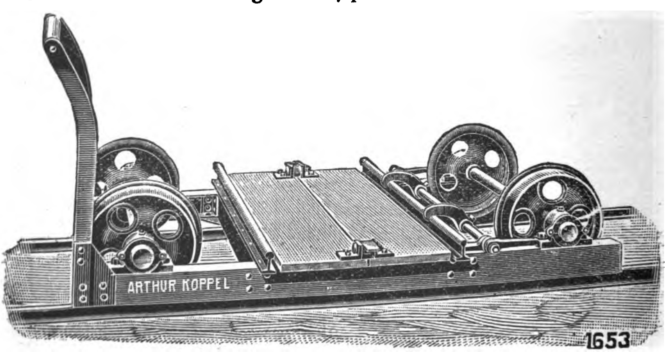

Fig. 121.

On this track runs the transfer car, the platform of which is provided with a transverse pair of rails 4ft. long, of the same gauge as the tunnel tracks.

This car may be placed so that the rails on it correspond to any one of the tunnel tracks. On receiving the car of dried bricks it is pushed on its track till opposite the main line of rails leading to the kiln.

Loading of the tunnels with wet bricks is, of course, arrived at in the reversal of these proceedings, on the transfer car at the cool end.

Transfer tracks are shown in position in Fig. 93. The transfer car costs about £8 10s. 0d.

TURNTABLES.

A second method of transfer is by means of turntables. The main lines of rails to and from the dryer are laid transverse to the tunnels. These lines are interrupted by fixed turntables either one for each track or one for every two tracks. The latter arrangement is shewn in Fig. 97.

The turntables for this cost £7 each, so that for any dryer up to four tracks the expense is approximately the same with either method. The turntable method is much to be preferred, as the transverse track may be continuous with the other tracks on the works, and does not interrupt or interfere with the general lines of traffic. The cars also are more quickly and more easily manipulated on the turntables than on the transfer cars.

CLIMBING TURNTABLES.

If it is desired to avoid expense, a very useful device is the portable climbing turntable, one of which at each end of the tunnels will suffice.

With this the dryer tracks will be run right up to the main track, which is continuous. The climbing turntable is laid upon this main track with sloping runners leading down on to the rails in three directions. Two sets are in one line with the main track, and the third leads down on to the tunnel track. The rise off the rails on to the turntable is only about three inches, and is no appreciable drawback to its use.

It is only necessary to slide the turntable along on the rails of the main track to bring it into use for the next, or any other, dryer track.

These turntables cost about £5 10s. each for tracks of 20-in. gauge.

Rails.

The rails used in drying tunnels should weigh not less than 14lbs. to the yard, and corrugated steel sleepers with well-designed clips and bolts are to be given preference over any other form of support.

If the tunnels have a sheet iron floor the plates may be punched to suit the gauge and the rails may be bolted to the plates. Fishplates, though not absolutely necessary, are such a small item of expense that it is well to use them. Small economies which may be made in these items are not to be recommended, as one breakdown through defective fixing will cost more to put right than the amount of the saving effected. The question of gauge must be decided according to individual opinion and the size of car adopted. The 20in. gauge is by far the most convenient for general use in a brickyard but cannot be adopted for cars more than 2ft. 9in. wide. In general it may be stated that a 20in. gauge track and a car about 5ft. 6in. long with 2ft. 6in. wheel base is more workable than any larger combination.

Slope.

The question of slope of the rail level is to be determined according to circumstances. There are drawbacks in adopting a slope at all, and the Continental engineers do not do so. If adopted it should be from 1 to 80 to 1 in 100. If too great there is risk of accident, and if too slight mechanical assistance is frequently necessary to propel the cars.

Pushing Apparatus.

As dryer cars are rarely, if ever, coupled, it is necessary to provide for pushing them through the tunnels, and two methods may be described—one manual, by means of a winch, and the other mechanical, by means of the automatic pushing apparatus mentioned in connection with the Continental inventions.

The former may be conveniently arranged as shewn in Figs. 122 and 123. A pulley block A is fixed in the floor of each track a few feet in at the cool end, just below the level of the rails *r*. From a hook placed over the rear buffer of the car F, which is to be introduced into the tunnel T, a steel wire rope *j* passes over the pulley A, under the door sill and round a second pulley B, placed horizontally.

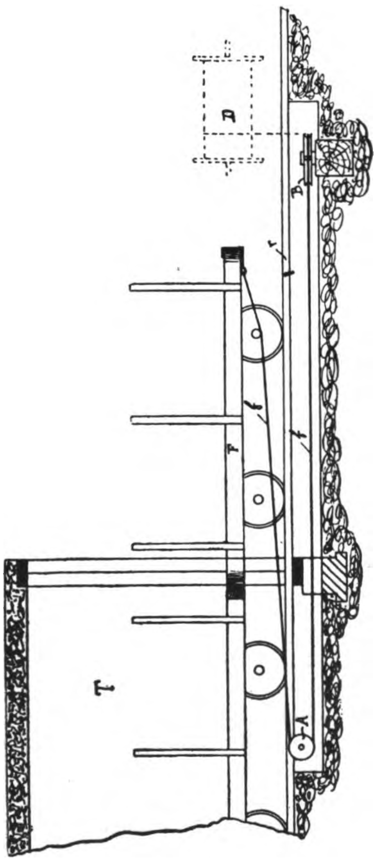

Fig. 122.

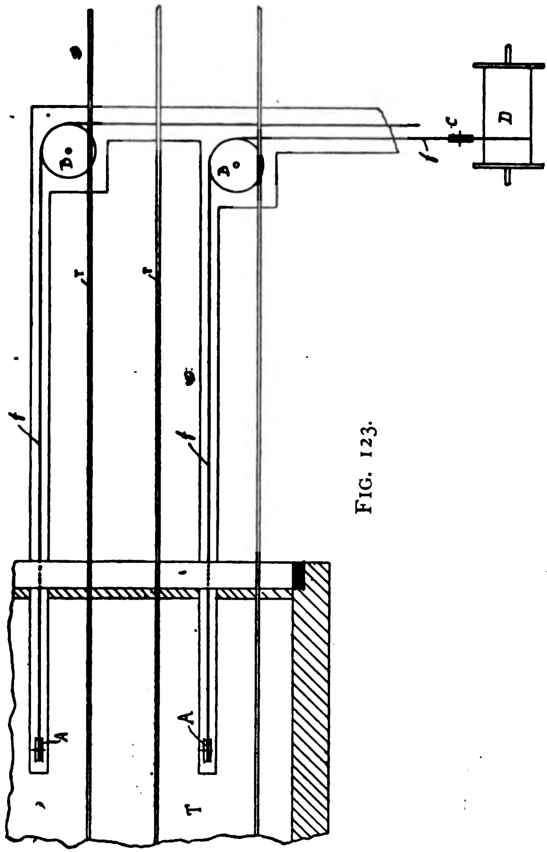

FIG. 123.

This changes the direction of the rope so that it now passes under the outer rail to a third pulley C, placed vertically, and then round the winch D.

When the car is thus drawn into the tunnel a dry car is at the same time pushed out at the other end. The rope and hook after use are left within the tunnel till required for the next

operation. Any number of ropes may be guided in this way to the same winch.

An apparatus of this kind is usually required at times, even with a considerable slope, as one or more cars may at any time become set in some way so that those behind it are prevented from moving forward when a dry car is withdrawn.

Details are not readily obtainable of the mechanical pushing apparatus, but the principle of it is shewn in Figs. 124 and 125 in diagram. With the requisite mounting, which is omitted in the drawings for clearness, this would prove a satisfactory arrangement.

The pulley A on a countershaft actuates a straight belt a^1 and a crossed belt a^2, both of which are shewn running on loose pulleys on each side of the fast pulley B.

If a^1 is shifted on to B, the train of gear B, C, D, E, is put in forward motion; if a^2, then in backward motion. The pinion D^1 on the last shaft D actuates a long ratchet E, which may be attached to the car F by means of a chain or rod *f*.

In the position shewn the apparatus is prepared to push the car F into the tunnel T, and this operation is started by pushing the belt a^1 on to the pulley B by a hand lever (not shewn).

With a speed of 200 r.p.m. on the pulley A, the operation will be completed in 20 seconds, the ratchet E having travelled the length of one car.

At this moment the pin *e* on the under-side of E will engage the pin g^2 on the reversing lever G, and will draw this lever along with it a short distance. G in its turn actuates the crank lever G^1 which is pivoted at *h*, and in this way the automatic belt lever carrying the guide H will, with the one motion, push the belt a^1 on to the loose pulley again and draw the belt a^2 on to the fast pulley B.

The crossed belt a^2 is thus brought into action and the train of gear draws the ratchet E back to its original position. Near the end of the travel the pin *e* engages the pin g^1 on the reversing lever G, with the result that the belt guides H push the belt a^2 off the fast pulley B on to the loose one, and the whole apparatus comes to a standstill in the position shewn in the figures.

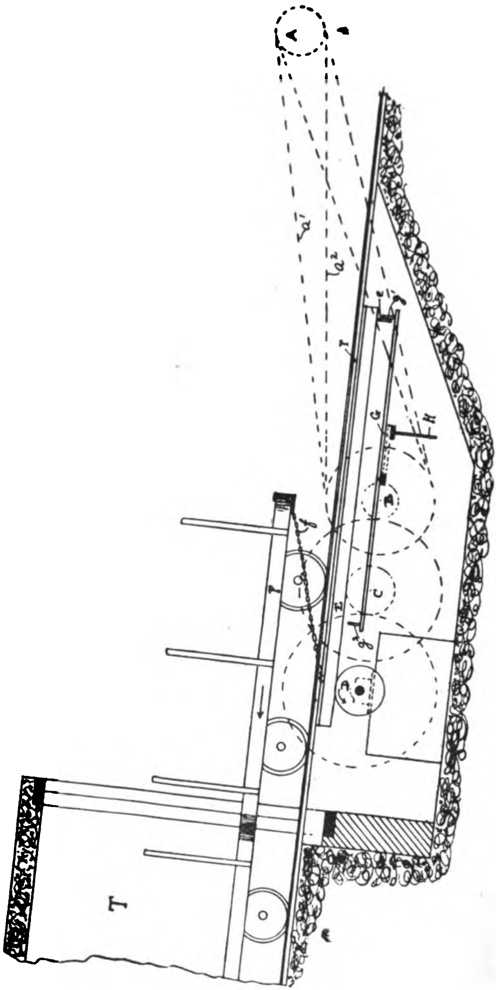

FIG. 124.

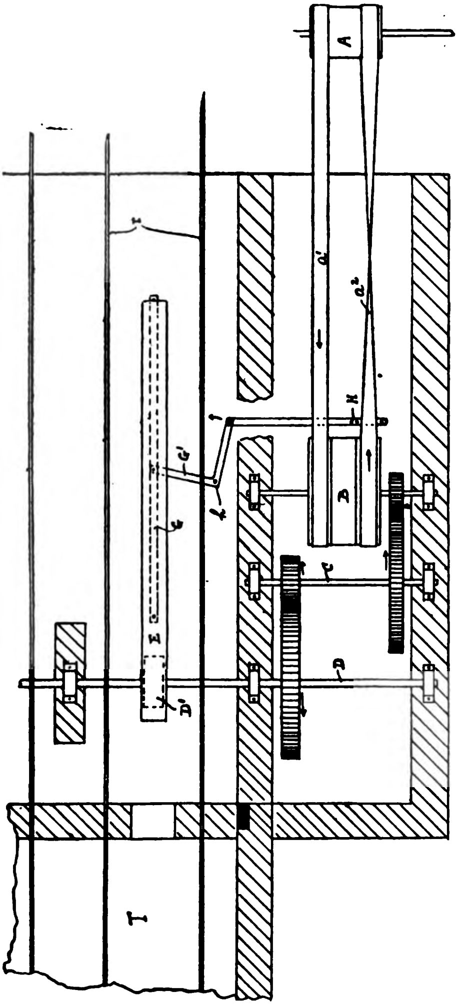

FIG. 125.

Such an apparatus dispenses with the necessity of a slope in the level of the tunnels. It would cost upwards of £100 complete for a four-track dryer.

General Construction.

It is usual to construct the outer walls of 9in. brickwork, and the roof of cement concrete. In many cases, too, sheet iron counterbalanced sliding doors are used.

It is interesting in this connection to study the two following tables, shewing (1) the conductivity of different materials, (2) the amounts of heat which some transmit per hour for each degree in difference of temperature of the air on the two sides of them, for every square foot of surface :—

Table VIII.

Gold	16·01	Concrete	·08
Iron	5·82	Sand or earth	·056
Lead	2·91	Cork	·03
Marble	·62	Wood boards	·02
Glass	·17	Sawdust	·014
Brick	·13	Cotton wool	·007

Table IX.

A 4½in. brick wall	·46	A door	·52
,, 9in. ,, ,,	·37	One-inch boards	·42
,, 13½in. ,, ,,	·27	Pasteboard	·62
,, 18in. ,, ,,	·23	Timber framing filled with earth	·10
,, window	·78		

The first table gives the absolute conductivity, which means that the number given is the amount of heat in British Thermal Units which will be transmitted in one hour through a square foot surface, one foot thick, if the temperature is one degree F. higher on one side than the other.

If the thickness is less, more heat will be transmitted, and also if the difference in temperature is greater ; in both cases the quantity being proportional.

This is expressed scientifically by the formula :—

$$Q = k \frac{a\ (t^1 - t^2)}{l}$$

where Q is the quantity of heat, k the absolute conductivity, a the area of surface in square feet, t^1 and t^2 the temperatures on the two sides, and l the thickness in feet.

The second table gives the heat transmitted through certain forms of construction, when in contact with air on both sides, The quantity must be increased by 30 to 50 per cent. on windy days or if the surfaces are much exposed.

An example of the application of these figures to practice may be taken as follows :—

Suppose a dryer 100ft. long with 9in. brick walls 6ft. high, with an earth-covered roof 15ft. wide. Suppose it heated uniformly and continuously inside to a temperature of 130° F., while the air outside is at 50° F.

Then by the formula—

Walls $Q_1 = \cdot 37 \times 1{,}200 \times 80 = 35{,}520$ B.T.U.
Roof $Q_2 = \cdot 10 \times 1{,}500 \times 80 = 12{,}000$ B.T.U.

Total loss of heat per hour, 47,520 B.T.U.

This is about the amount yielded by the consumption of 4½ lbs. of coal, and corresponds to the loss of 1 cwt. per day.

With 13½in. walls the loss would be reduced by 9,600 B.T.U. per hour, or one-fifth of the whole.

With a cement concrete roof the loss would be increased by about 6,000 B.T.U.

The loss through sheet-iron doors would be very large, though it is limited by the rate at which the external air can carry off the heat. Wood doors should therefore always be used.

A practical illustration of the amount of heat which passes through the roof, is seen in the case of the Bucyrus dryer (American Clayworking Machinery Co.). In this, in its continuous form, the ceiling is covered with earth, and air is admitted into the space between the ceiling and roof and passes thence into the tunnels. It becomes warmed to about 80° F. at the hot end.

The amount of heat (Q2) shewn to be transmitted under such conditions in a four track dryer would warm up a volume of about 400 cubic feet of air per minute from 50° to 80°.

The general deductions from these figures are that 13½in.

walls are advisable, and may be further improved by forming 2-in. hollow spaces in them; that the best covering is formed by match-boards covered with sawdust, and that the doors should be of thick wood.

Galvanized corrugated iron may conveniently be used as an outside roofing over the sawdust.

CHAPTER IX.

Cost of Installation.

As a guide to the cost of installing tunnel dryers, the following estimates for different systems may be of use.

In every case a four-track dryer is given, and its capacity, if provided with double deck cars loaded nine high. In the case of the Möller and Pfeifer dryer the capacity is that with the German type of car.

I. Blackman.—Simple typical form with slab heater. Tunnels 120ft. long. Capacity 24,000 bricks:—

95 cubic yards brickwork.
8 „ „ firebrick.
55 „ „ cement concrete.
1½ tons steel joists; 4 pairs of doors; car decks.

Furnace fronts, firebars, 48in. fan, rails and cars, for a sum of £450.

Estimated cost per 1,000 bricks capacity, £30.

II. Blackman or Sutcliffe.—Simple typical form with tubular steam heater. Same length and capacity:—

75 cubic yards brickwork.
40 „ „ concrete.
1½ tons steel joists; 4 pairs of doors; car decks.

Tubular steam heater, 48in. fan, fittings, rails, and cars for a sum of £625.

Estimated cost per 1,000 bricks capacity, £35.

III. American Blower Co.—Simple typical form with heating apparatus (1in. tubes). Same length and capacity :—

Brickwork, concrete, joists, &c., as last.

Heating apparatus, fan with coupled engine, fittings, rails and cars for a sum of £850.

Estimated cost per 1,000 bricks capacity, £45.

IV. Blackman.—Efficient form with combination of waste kiln gases, and tubular steam heater, with flue beneath track covered with iron and flue above ceiling. Same length and capacity :—

120 cubic yards brickwork.
40 „ „ concrete.
2 tons steel joists.
4 „ sheet-iron floor and ceiling.
Doors as usual. Car decks.

Tubular steam heater, fan, &c., as before for a sum of £625.

Estimated cost per 1,000 bricks capacity, £40.

V. Wolff.—With 30ft. tempering chamber and 98ft. drying chamber. Capacity, 39,000 bricks :—

110 cubic yards brickwork.
780 „ feet timber framing.
6,250 square feet 1in. boarding.
3,200 „ „ roofing material.
16 sliding doors ; 6 windows ; car decks.

Complete pipe heaters, fittings, valves, pump, rails and cars for a sum of £800.

Estimated cost per 1,000 bricks capacity, £33.

VI. Bucyrus Dryer (in its continuous form).—Tunnels 80ft. long. Capacity 22,000 bricks :—

85 cubic yards brickwork.
50 „ „ earth filling over ceiling.
250 „ feet timber framing.
4,400 square feet 1in. boarding.
2,200 „ „ roofing material.
4 pair doors. Car decks.

Complete pipe heaters, fittings, valves, pump, rails and cars for a sum of £550.

Estimated cost per 1,000 bricks capacity, £35.

VII. MÖLLER & PFEIFER.—Tunnels 174ft. long. Capacity 20,000 bricks :—

460 cubic yards brickwork.
5,400 square feet roofing material
6½ tons steel joists.
Doors. Car pallets.

Heaters (41 tons), fans, fittings, rails and cars for a sum of about £1,500.

Estimated cost per 1,000 bricks capacity, £125.

VIII. BROWN.—Tunnels 136ft. long. Capacity 31,000 bricks :—

200 cubic yards brickwork.
2,350 square feet roofing.
3 tons steel joists.
1½ tons sheet-iron.
Doors. Car decks.

Heaters, fan, fittings, rails and cars for a sum of about £1,000.

Estimated cost per 1,000 bricks capacity, £42.

The cost of installation must also be viewed from the points of view of output, efficiency, and suitability to the material to be dried.

Thus, for instance, with a clay which may be dried in 24 hours or less, the estimates I., II., III., IV. and VI. represent the cost per 1,000 bricks dried per day.

Estimate V., however, for the Wolff dryer does not stand, for bricks are not dried in it in less than two days, which brings the comparative cost per 1,000 dried up to £66, if a tempering chamber is used.

On the other hand, such clays may be dried in the Möller & Pfeifer tunnel in 16 hours (Estimate VII.), which brings down the comparative cost per 1,000 dried to £83 on this system.

Further, it is evident that if a clay takes three days to dry in any of the systems I. to VI., the estimate must in each case be increased to three times the amounts stated. Here again, Möller & Pfeifer probably have the advantage of a reduction, for they assert that the most tender clays may be dried in one day in their system.

If their assertion is actually proved, then their system is cheaper in first cost for this class of material than any other.

In this connection it is as well, perhaps, to tabulate the installation cost of a series of the drying systems described in this treatise. In order to render the tables uniform, the installation cost stated is that incurred per million bricks production per annum.

TABLE X.

		£	Area covered.
	With Summer working only.		
1.	Common stock brick hacks without loo-boards	120	1 acre
2.	Do. do. with loo-boards	175	"
3.	Erected hack roofing with loo-boards...	400	"
4.	Do. do. with hinged shutters	500	"
5.	Unwarmed sheds with racks	800	½ acre
	Working all the year round.		
6.	Sheds over Hoffman kilns, simple form	600	450 sq.yds.
7.	Sheds with coke-heated floors ...	400	900 "
8.	Do. with steam-heated cement floors	250	350 "
9.	Shed with racks warmed by steam pipes	350	800 "
10.	Hooper & Co.'s floor	200	225 "
11.	Keller's dryer	300	140 "
12.	Schaaf's dryer	250	600 "

TABLE XI.

Progressive Tunnel Dryers.

	NAME.	Bricks easily dried. Cost in £.	Bricks easily dried. Area in sqre. yds.	Bricks easily dried. Time taken in days.	Moderately easy to dry. Cost in £.	Moderately easy to dry. Area in sqre. yds.	Moderately easy to dry. Time taken in days.	Difficult to dry. Cost in £.	Difficult to dry. Area in sqre. yds.	Difficult to dry. Time taken in days.
13	Blackman, with slab heater	100	30	1	...	...	...	...	...	...
14	Blackman or Sutcliffe, with tubular steam heater	117	30	1	...	...	...	...	...	...
15	A.B.C. dryer	150	30	1	...	...	...	...	...	...
16	Blackman "improved"...	133	30	1	400	90	3	...	...	...
17	Wolff (without tempering chamber	200	45	2	...	...	...	...	...	...
...	Wolff (with tempering chambers)	...	...	...	330	80	3	...	...	...
18	Bucyrus	117	25	1	290	63	2½	468	100	4
19	Möller and Pfeifer	278	53	⅔	417	80	1	625	120	1½
20	Brown	140	30	1	280	60	2	420	90	3

The actual cost will be greater than here stated if a dryer of less than four tracks be constructed.

It will be evident at once from these figures, that, considering the small space occupied and the independence of weather conditions, the tunnel dryer must be the dryer of the future, wherever it is successfully applicable to the class of goods to be manufactured.

COST OF WORKING.

Turning now to the working cost of tunnel dryers, it is necessary in calculating the cost of labour to decide the number of hands required for a production of, say, 20,000 bricks daily from the moulds or cutting table to the door of the kiln.

This is a medium production and may be obtained with certainty from a five-track dryer of almost any design.

Two men or strong boys can load this quantity on double-deck cars in ten hours and two men can wheel the cars to the dryer and wheel away the dry cars to the kiln.

The labour of serving the dryer, therefore, is from 10d. to 1s. per 1000. This is, of course, increased for a smaller production and decreased slightly for a larger.

In addition to this the cost of a stoker at night should, strictly speaking, be added, but wherever continuous kilns are in use (as in these days they always should be) the night burner can quite well attend to the dryer. In such cases ½d. per 1,000 would cover cost of labour at night, and where intermittent kilns are used, 2d. per 1,000.

The cost of power must be considered in all systems where fans are used. It amounts to about 2d. per 1,000 in the systems mentioned, except in the Möller & Pfeifer, in which it must be put at 4d. per 1,000. The steam power for the fans is supposed to be provided by the main boiler which also furnishes the live steam for night working. The exhaust steam from the fan engine should also be made use of in the dryer.

Fuel cost varies from 8d. to 1s. 3d. per 1,000 according to the system adopted. These figures presume coal at 12s. 6d. per ton, and the use of exhaust steam by day and live steam at night. The bricks also are taken to contain 1lb. of water, and if they contain 1½lbs. the fuel cost will be increased 25 per cent.

Putting these items together it appears that from 1s. 8d. to 2s. 6d. per 1,000 is the entire working cost of drying the bricks in tunnel dryers under the conditions named. These figures may be compared with those stated (p. 32) for hack drying, 3s. 3d. to 3s. 6d. per 1,000, while drying on a steam floor may be put at 3s. to 3s. 3d. per 1,000 for labour and fuel. An immense further advantage in the use of tunnel systems is evident, for the bricks are loaded direct on to the cars at the machine and are not damaged in any way by handling or accidental injury before reaching the kilns.

NIGHT WORKING.

Strictly speaking, all continuous dryers should be worked continuously, that is, bricks should be introduced wet and withdrawn dry at regular intervals day and night.

In practice this is not convenient unless the output is very large. It necessitates also an additional number of cars which require to be loaded during working hours and put aside for night use.

The difficulty can be met only by supplying less heat and ventilation at night and more during the day, but it is in any case worth while to have two or three extra cars per track, which can be left in a convenient position so that the burner or stoker can put them into the tunnels at night.

Manufacturers frequently make objection to the systems employing fans because of the power required and of the fact that the fans must be kept running at night. This objection has no real existence in fact, because, as explained above, the kiln burners may and do take charge of the dryers at night. Moreover, wherever steam is used, no matter in what form of dryer, it is necessary to have a night stoker always employed He may take charge of the fans at the same time as the boiler.

IMPORTANCE OF THE SUBJECT.

One word in conclusion may be of value in emphasising the importance of giving very careful attention to the subject of "Brick Drying" in all brick works.

It is a subject which has received very inadequate study until quite recently, but the growth of large works and the increasing

cost of labour at the present time render it imperative to give serious thought to it. It is seldom realised that dryers, no matter of what type, are in many cases more costly to install for a given output than kilns or machinery. The figures given in Tables X. and XI. show that the cost of installing dryers for an output of 3,000,000 bricks annually, working all the year round, is from £600 to £1,200, according to the system adopted and the nature of the clay to be dried.

The most expensive type of kiln does not cost more than £1,000 for the same output.

For an output of 6,000,000 annually the dryers will cost from £1,000 to £2,000, whereas a kiln for the same output could be built for about £1,600.

Again, it is rarely realised that the fuel expenditure on artificial drying, except with the most efficient dryers, is nearly as large as that on burning in continuous kilns. This is due to a haphazard way of taking measurements of it, for the manufacturer will usually tell an enquirer that his exhaust steam will do all the drying with the assistance of only a load or two of coal for keeping the boilers under steam at night. The consideration of back pressure on the engine and of the cost of the "load or two" used at night is neglected, but can easily be shewn to be of great importance.

It has been endeavoured in this treatise to put the whole of the facts as at present understood on the subject of "Brick Drying" in such a way as to enable the manufacturer to comprehend the essential scientific features and the practical difficulties of it, so that he may be in some measure competent to form an independent judgment as to the type of dryer most suited to his class of trade.

It has, of course, been impossible to go more deeply into the merits of individual dryers, but every endeavour has been made to obtain information of a trustworthy nature and to supplement it by impartial critical examination of the scientific conditions obtaining in each case.

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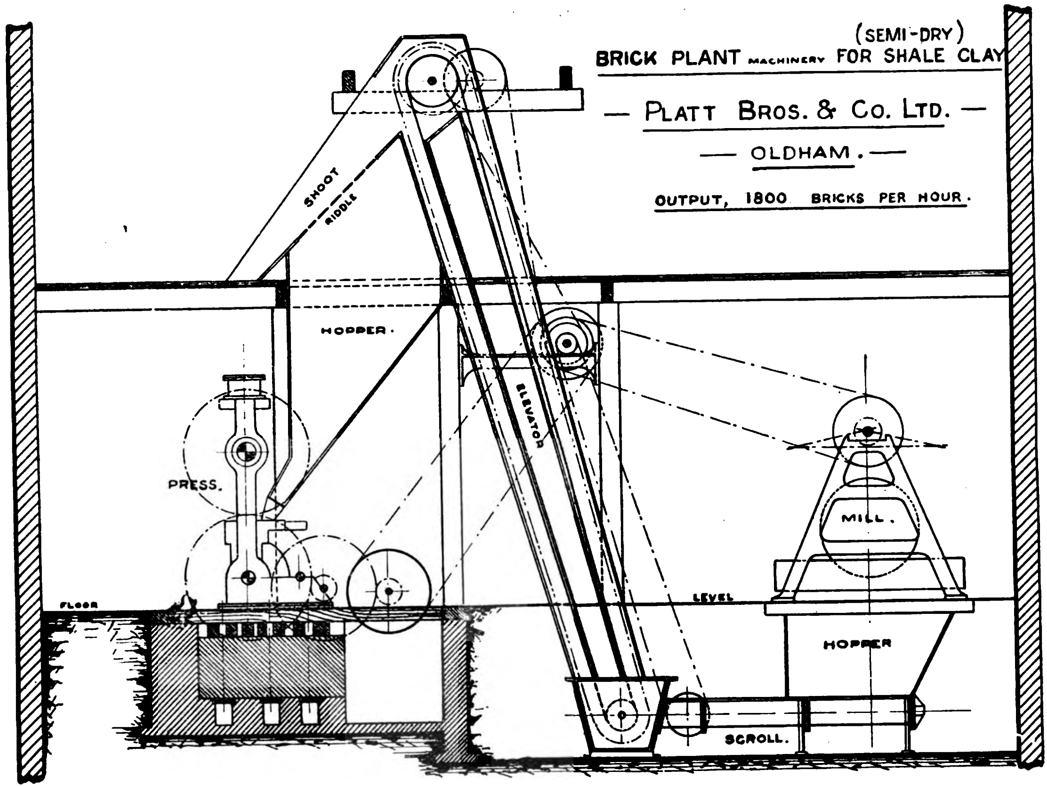
TABLES.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